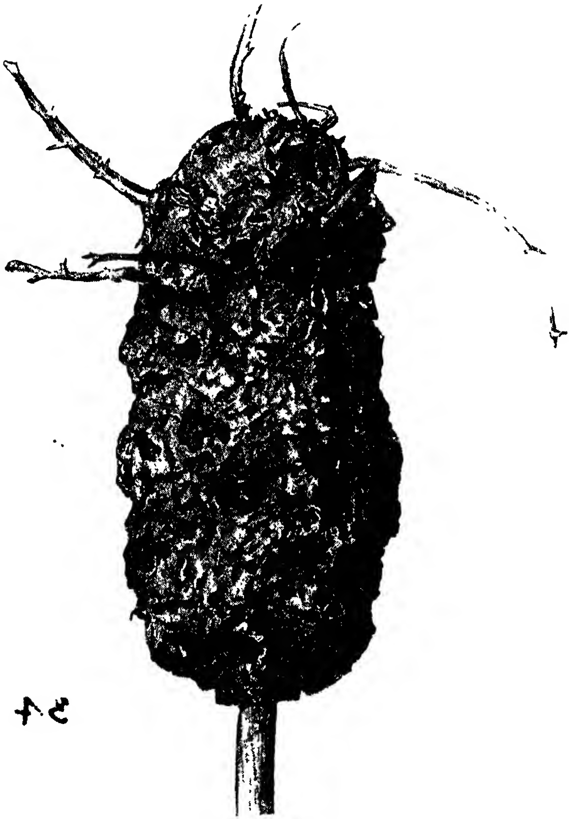
ROMANCE OF THE INSECT WORLD



NEST OF A TREE ANT.

ROMANCE

OF

THE INSECT WORLD

BY

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WITH ILLUSTRATIONS

BY MARGARET J. D. BADENOCH AND OTHERS

LARVA OF THE CADDIS FLY (*Trichoptera*)

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TO

MY MOTHER

A Token of Affection

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ROMANCE OF THE INSECT WORLD

NOTE.—*An asterisk indicates that the word so marked is mentioned in the Glossary.*

CHAPTER I

METAMORPHOSES OF INSECTS

Character of life-history of insects — Metamorphoses of the butterfly, beetles, &c. — "Similarly-changing" insects — The two series Heteromorpha and Homomorpha — True metamorphic stages considered in detail — egg — larva — shelters for approaching change — Meaning of pupa and other terms applied to stage — Nature of condition in insects which undergo complete metamorphoses — Signs of returning life — Assumption of imago state — Pseudo-imago — Subsequent career — Old idea of metamorphoses — Modern theory — Study of structures implicated — External — Modifications of internal organs — Explanation of metamorphoses — Apparent suddenness of changes — Of the death-like period of quiescence.

IN these days of universal education, no doubt it would prove a somewhat hard matter to discover any number of persons who were altogether unacquainted with the wondrous phases of insect existence. Many would be found aware, few not, that during the period of their life-history, from birth

to infancy and on to maturity, the great majority of the members of these little lowly winged tribes pass through a series of changes of condition, and assume several successive well-marked forms, to all appearances totally distinct the one from the other. In a general way the youngest persons, and the most ignorant, are informed of the fact, but how many, learned and ignorant and young alike, ignore it, owing to the commonness of the occurrences and the minuteness of the objects, and thus deprive themselves of the exceeding interest and pleasure to be gained from study of this, which is perhaps the most admirable of all the extraordinary pages of natural history.

The butterfly, whose metamorphoses are so striking to the young, could have never existed as we now behold it, had it not successfully accomplished a regular series of changes of structure since the day of its birth. It is produced by the parent as an egg, from which it is hatched in the shape of a caterpillar or larva, a worm-like creature of soft and fleshy consistence, furnished with a mouth and a few short legs, its only requirement being an abundant supply of food. Of this it eats with an incomparable appetite, and makes haste to grow, necessitating repeated casts of skin. Eventually it becomes a shrouded chrysalis or pupa. This sleep being over, it awakens to a new life, having little resemblance to its old condition, in its aspect, or internal conformation, or in the work that has

then to be done,—a winged and perfect butterfly. In the case of beetles likewise, the larvæ or grubs at their emancipation from the egg, though they differ much, are all more or less in an immature stage. Gradually the larvæ alter to the quiescent pupæ, the nymphs so-called, and from the pupa emerges the perfect beetle. Bees, wasps, flies, and many more undergo similarly marked metamorphoses.

The metamorphoses of some insects, however, are far less decided, as in the grasshoppers, locusts, crickets, earwigs, and a small group well-known to gardeners under the name of thrips. In these the larvæ and pupæ already greatly resemble the fully-developed parent. The changes consist principally in a gradual increase of size, with casts of skin, and as pupæ the insects begin to show signs of the acquisition of wings. In certain cases the egg-stage is wanting, the larva being produced alive. There are rare anomalies in which development has been carried to a considerable degree before birth.

The difference in the nature of metamorphoses has given rise to a simple division of insects into two series: Heteromorpha, according to Professor Westwood, or those in which there is no resemblance between the parent and the offspring; and Homomorpha, or those in which the larva resembles the imago, except in the absence of wings. In the former the insects may be said to undergo

complete metamorphoses; as regards the latter, their metamorphoses are incomplete.

It may be laid down as a universal law that all insects originate from eggs. The apparent exceptions comprise the few instances where the young are hatched, or are retained within the body of the mother. The varieties of eggs it is almost impossible to enumerate, among the butterfly families especially scarcely two forms are alike, even in the most closely allied species marked diversity occurs. They may be round, oval,* oblong, pear-shaped, lenticular,* or flattened like a lens. Many of them are petiolated,* or placed upon foot-stalks, which may be long and straight, or comparatively short and bent. Others are provided with particular appendages to answer various ends. They are enriched with all the colours of the rainbow, though the prevalent hues are white, yellow, and green. Sometimes the outer coat is hard and firm, sometimes it is a mere filmy skin. The surface may be smooth and plain, or beautified with delicate sculptured designs, such as cross lines giving a reticulated * appearance, or these lines may be curved, as if the eggs were imbricated * or covered with tiles; or the pattern may assume the form of decided knobs. The variation in external shape, markings, and colour is not greater than in the modes of disposition of the eggs, and the localities where they are placed. They are laid singly or in clusters, and for the most part upon, or within,

or near the substance, be it plant or animal, which will serve as the food of the larvæ that will presently be hatched from them. As a rule, the peculiarities of form and colour bear relation to the circumstances of disposition, the objects to be ensured being safety from external injury and the proper development of the egg. Those eggs from which the larvæ are most rapidly developed require the aid of the highest temperature and the fullest exposure to the atmosphere.

Usually the formation of the larva is complete soon after the egg is laid, sometimes the process lingers on throughout the winter, and should unfavourable circumstances supervene, it is surmised that it may be delayed for years. Experiments prove that eggs may be exposed to intense cold, such indeed as to solidify their contents, and yet remain capable of hatching. The growth of the embryo* within the egg may be watched. This is easily perceptible in the case of a transparent egg, by holding it against the light, or by examining it through a strong magnifier. Day by day the germ steadily increases from a tiny speck, until it is too large for the egg to contain, and it breaks through the now tight skin or shell, and emerges into the world a living and active being — the grub or larva.

The word larva is from the Latin, and signifies a mask or phantom. It was applied by the great naturalist Linnæus to the first active stage of in-

sects, with the idea that during its continuance the glories of the future perfect creature were, as it were, masked or shadowed out. Unhappily there is no corresponding general term in English. The larvæ of moths and butterflies, which are coloured and often hairy, are spoken of as caterpillars. White fleshy and more compact larvæ, legless, or possessed of legs, as those of many beetles and flies, are commonly known as grubs and maggots. Such as resemble the parent, as a rule are designated by the parent's name.

It is interesting to follow the life-history of an insect that is subject to true metamorphoses. From the moment of its liberation from the egg as a larva * until it assumes the perfect form, its life is one continuous succession of changes. These are not merely from larva to pupa, and from pupa to perfect insect, for even while it is a larva it undergoes a series of sheddings of skin, or moults as they are called, previous to its attainment of its full size and growth. No sooner is a caterpillar hatched than it begins eating, its first meal often consisting of its discarded egg-shell. Perhaps this dainty morsel tempts the appetite, at any rate the hunger that the insect displays, and the amount of food that it requires to satisfy it are something wonderful. Naturally it increases immensely, and the skin has to stretch to allow of the greater bulk. By and by there comes a day when the skin will extend no more, it cracks,

and the larva crawls forth, clad in a bright new coat. The process evidently produces the greatest discomfort and uneasiness. A few hours before the divestment begins the larva ceases to eat, and remains motionless, meanwhile the body suffers powerful twitchings and contractions. But when once the skin yields — it splits down the back — the actual withdrawal from the clothing is seldom of long duration. The external covering of the body is not the only thing that is cast. The whole internal lining of the mouth and the digestive canal, and that of the respiratory organs are likewise detached and come away with the skin. This change, though it is most conspicuous at the last moult of the larva, probably takes place at the occurrence of each shedding.

After the operation, the creature is soft and languid, and pauses to recover from its exertions. Then it begins nibbling and devouring with increased voracity, since its digestive organs are now more capacious. Some insects make a fresh start with their old skin, but many at once remove to new feeding-grounds. Soon further enlargement necessitates a second change. The moults * vary in frequency in different species; in general they occur about three times, or oftener. Usually the first takes place about the twelfth day, the second after the further lapse of a week, the third happens six or eight days later still, the power of consumption of food at each moult being augmented.

Sphinx ligustri, the Privet Hawk Moth, is known to increase at the rate of over 11,000 times its original weight in the space of thirty-two days, a proportion, great as it is, largely exceeded by the goat moth, which increases to the amount of no less than 72,000 times its first weight, but this larva is very long-lived. Reason for the immense storage of food is found in the fact that all growth is effected in the larva and pupa stages, for when the insect becomes perfect it alters no more. The pupa * period is not only a state of death-like sleep, during which no food can be taken, it is the time when occurs the most rapid development of the tissues of the body. The nourishment accumulated by the larva has to admit of these alterations, and has likewise perhaps to serve as an immediate source of nutriment to the insect on its awakening at the end of the important pupa season.

In some cases the duration of larval life extends over one, two, or even five years. In all species it is much influenced by the weather and other circumstances, for cold as a rule retards growth and warmth hastens it. Many larvæ have an almost unlimited power of endurance of cold, and may be frozen hard without the slightest injury. That a severe winter is highly beneficial for the crops in precluding probability of insect attack in the following spring is utter fallacy. But though larvæ will bear great cold, they are extremely susceptible to over-supply of moisture, whether

from rain or from dampness of food, a characteristic worthy of consideration when attempting to exterminate an insect pest.

Suppose that an insect is near the completion of its term of growth, when for the last time as a larva it will cast its coat, and will emerge therefrom in the next stage of its existence — a pupa. Great changes in its internal organs since its exclusion from the egg are beginning to take place, and greater ones are yet to come. As before its previous but less momentous larval skin-sheddings, it seems to suffer inconvenience, it becomes exceedingly restless and irritable, it neglects food and diminishes in weight, and, as if aware of its distressing delicacy and defencelessness when the skin is abandoned, as a rule it makes haste to seek or construct some shelter with care and consideration, where, secure from harm, the otherwise disastrous revolution may be effected, and the hapless stage of pupal life may be lived through. Many species, like the silk-worm caterpillar, secrete and draw a gummy fluid from their mouths, and spin a cosy silken nest or covering around them, known as the cocoon; * occasionally the silk is mingled with particles of wood or earth. Some of the butterflies simply suspend themselves vertically by their hindermost legs, head downwards, or they carry a silken cable across their body to keep them from falling, affixing the girdle to the under-surface of an object such as a leaf or twig.

Many insects hollow out a cell or cavity in the ground and line it with web of silken material. The larva being duly prepared, after a short repose its skin splits, and with infinite shuffling and wriggling is thrown off, and then the insect is known as a pupa. In the true flies the outer skin of the full-grown larva is not shed, the maggot contracts, while the skin gradually hardens, assuming the appearance of an oval brownish shell or case, which serves the same purpose as a cocoon and affords an admirable protection to the insect which changes to pupa inside.

FIG. 1. — Pupa of a butterfly (*Pieris brassicæ*) protected by a hardened uniform case, secreted from the pores of the insect.

The being that emerges in its bright new coat is very different from the larva, for the muscles have already shortened and enlarged in certain parts, so modifying the simple worm-like form that the entire shape and limbs of the future perfect creature are apparent, and the wings, though they are very small and in rudimentary condition, may be plainly traced. The new pupa, should it be that of a butterfly (see Fig. 1), as of Sphinx, having got rid of its larval skin, hangs for a few seconds at rest. It suffers some powerful contractions and alterations, and the wings become much enlarged;

moreover, a very transparent fluid secreted from the pores which facilitated the slipping off of the discarded skin, is now diffused over the whole body, and as the insect sinks into quiescence, dries and hardens into a compact protective covering, uniting and supporting the tender and erstwhile separate limbs.

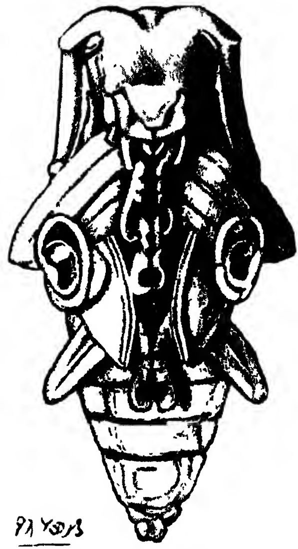

FIG. 2 — Pupa of a longicorn beetle (*Batocera titana*), its limbs in separate sheaths folded beneath the breast and body

To the pupa the terms nymph, chrysalis, and aurelia are also given. The two latter names were used by the older entomologists, the first by the Greeks, the second by the Romans, for this stage of transformation in the butterflies and moths, being expressive of the glittering golden colours or spots with which many pupæ of butterflies are adorned. "Nymph" is applicable only to those pupæ in which the limbs remain free in separate membranous skin-sheaths, folded beneath the breast and body (see Fig. 2), as in many of the beetle and bee tribes, unlike the common uniform covering of Lepidoptera. At present the term is

usually confined to active Homomorphic insects when in this stage. The word pupa itself, meaning an infant, was adopted by Linnæus as a general term for the period. It is peculiarly appropriate, for insects in this state are approaching their completion, but are not fully developed, either in their limbs or functions, and in many cases recall the condition of a child swathed or bound up as in barbaric fashion. The pupæ of flies, where the insect is enclosed within the smooth uniform case formed of its own cast larval skin, but no limbs and other parts of the body are visible externally, is called "coarctate." *

In insects which undergo complete metamorphoses the pupa is a most remarkable and characteristic condition. Almost as long as the state continues, the insect usually lies quiescent, capable of only the faintest motion when touched, in a seeming deathlike torpor, tasting no food, and the vast change which was beginning when in many instances the larva took shelter is gradually completed, incapacitating the creature for a continuance of its previous life, while adapting it for life in the future. It is no wonder that the period of such organic evolution is at the same time one of great functional inaction, which lasts longer than the rest succeeding each minor skin-shedding that has gone before. Respiration and circulation, for instance, are reduced to a minimum. Some insects remain in pupa for a very

long time, particularly true of the Sphinx moths, which often continue in chrysalis for nine months of the year. But on the other hand, as regards ants and bees and many others, it is the shortest period of all, and occupies little more than a week or ten days. In every species the length is much affected by the weather. Should a butterfly larva turn to pupa during the summer, it may become perfect in eight or ten days, but if it reach the chrysalis state at the approach of winter the change to butterfly may be delayed for months, until development is quickened by the warmth of returning spring. Reaumur discovered that if a chrysalis were deposited in an icehouse, further transformation might be retarded for two or three years. If one deep in its winter sleep were brought in from the cold to great heat, the final metamorphosis might take place in ten or fourteen days.

As the structures become completed, and the hour for entering the imago condition draws near, the immobile pupa begins to show signs of returning life. In Sphinx respiration increases rapidly, twitchings and contortions indicate what is about to occur, and the form of the coming insect becomes more and more apparent. In every instance the assumption of the perfect state is accompanied by a casting of the outer skin. Before this can be effected, many insects have first to acquire the power of locomotion. Caddis flies which undergo

their previous metamorphoses in water, must be able to come to the surface, or to quit an element in which they cannot now exist. Pupæ that are lodged in the interior of trunks of trees, or in crop stems, or beneath the ground, usually issue forth from these situations; and many Lepidoptera and others have to struggle through silken wrappings. Having overcome the obstacles that oppose its escape, the pupa bursts its covering, and the insect emerges perfect in all its parts. Sometimes a little while elapses ere it takes to flight. The wings of butterflies and moths are somewhat drooping and difficult to spread, and the body is humid and soft. After considerable respiratory effort, and a rest, and exposure to the drying influence of the atmosphere, the imago gains strength and solidity, its wings enlarge and expand, and at last it enters on its higher career and the delight of finished faculties. Humble bees do not at once come abroad to the outer air in their new dress. Their bodies are excessively moist and weak when they emerge from the cells, and their hairs are of a whitish gray. They crowd together in the nest, and seem to feel the chill of diminished warmth. In a few hours the susceptibility vanishes, and the proper colours are acquired, but the bees are not vigorous or capable of great exertion until the following day.

When an insect has withdrawn from the pupal case it is perfect in form, its internal organs are

perfect, and metamorphoses are now concluded. An apparent exception to the rule occurs in the case of the May-flies (Ephemeræ).* The pupæ creep out of the water, and perform the feat of getting rid of the pupal covering, their wings expand, and they take feebly to flight. Shortly however they settle again, and having shed an extremely delicate skin, renew their aerial excursions with redoubled energy. The condition previous to the final moult has been called the pseudo-imago.

Metamorphoses being over, the task for the remainder of life, which is often an ephemeral span, is to propagate the kind. Numerous adults perform this work unhindered by any other desire, even that of partaking of food. The female lays her eggs, and then (usually) dies, and so the cycle of existence is complete. Many an insect lives merely one short year. Generally speaking, it is in summer or autumn that the parent produces the eggs, which quickly hatch, and in the state of larvæ, or more usually pupæ, the young hybernate, or sleep in shelter during the winter, and become perfect in the following spring. The mother seldom long survives the laying of her eggs. However, these points are liable to much variation, according to the seasons and the different species.

The term metamorphoses or transformations which is applied to these changes that insects

undergo as life proceeds, before they arrive at their perfect state, is at first maybe a little misleading. From the earliest times civilised nations have produced students of nature who have marvelled at, and watched, and endeavoured to explain these strange alterations. The old ideas on the subject were wide of the truth. It was believed there took place a complete transformation of one being into another — a transformation as startling as though a serpent turned to a bird — and that the most singular poetic bygone fables of metamorphoses were repeated in the case of insects. Modern research, aided by the microscope, has proved this opinion to be incorrect. These transformations are so many stages or seeming pauses in the natural course of a progressive development or evolution of the one self-same animal. The caterpillar in the egg is already possessed of the principal vital organs, which have to be modified and perfected; others appear later on; and often early-existing structures die away as growth advances. Nothing will more plainly show the fact that metamorphoses are but a progressive development of the immature into the mature being than a brief examination of some of the structures which are altered, and of those which put in their appearance during the successive stages of life.

An insect may be broadly defined as an animal that is formed of a series of rings or segments.*

They can be traced in the embryo within the egg, they are seen plainly in the larva, and can be distinguished in the perfect insect. The normal number of distinct rings in all insects is probably thirteen. The first constitutes the head. In most larvæ the remaining twelve are equally developed and differ little from each other in general appearance. But an imago is evidently distinctly divisible into three pieces — the head, the body or thorax, and the abdomen. However greatly the forms of these regions may vary, the difference is simply due in each case to greater or less development of the primary segments, and in many cases the various segments can be satisfactorily numbered and recognised. A difficulty lies in the fact that the changes are not brought about by alteration in the consistence of the integuments only, but by the union of several segments into one or more separate consolidated portions, and by the greater or less retraction of segments, each within the one which immediately precedes it. Thus their number becomes diminished, yet a segment never entirely disappears, but invariably leaves trace, however faint, of its former distinction. So far as can be ascertained, the second, third, and fourth rings of the larva go to form the thorax of the perfect insect, the remaining nine constitute its abdomen. The fifth however enters in part into the composition of the thorax and forms the connection of that portion with the abdominal

region. It is frequently atrophied,* and has almost entirely disappeared. If this piece be excluded, the abdomen is composed of eight segments. Any deviation from the rule in regard to reduced numbers will be found to be apparent and not real.

The larvæ of some insects are entirely destitute of legs and feet, as in the bee family and among flies, and the body is otherwise modified where power of locomotion is required. Many larvæ, however, possess pedal * appendages of two classes. These are true legs, six in number, arranged in pairs, always on the three segments of the thorax. So-called false or abdominal legs are attached to the segments of the abdomen, their number ranging from a single couple even to eight pairs. The true or thoracic legs of young insects are very small and scale-like, and are distinguished from the false legs by distinct articulations or joints, by their strength and firmness of texture, and their general pointed form. The whole of these thoracic legs in all larvæ that possess them are nearly equally developed. In structure and appearance the false legs are totally different. They are soft and membranous,* and their formation is often exceedingly curious; in every instance they are only processes * of the exterior covering of the insect. But the difference between the two kinds which must be particularly pointed out is this. The true legs are those which

enlarge and otherwise develop into the limbs of the future imago, whatever be their size or variety of form, whereas the abdominal legs are not persistent,* but are lost with the cast skin during the metamorphosis of the larva into chrysalis. Here then is a clue admitting of the recognition with certainty of the individual segments that compose the thorax, however much the distinction between them may have become obliterated in course of development. Each pair of legs in the perfect insect answers to each pair of true legs in the larva.

In the case of larvæ that are destitute of true legs, these wonderful organs have to be developed with all their muscles and nerves during metamorphoses.

The thorax,* which thus gives origin to the legs, is usually large, and the union of the segments is firm in proportion to the rest of the body. On the size of these segments and their consolidation greatly depends the strength of the insect. This region also supports the wings; to be precise, these appendages are attached to the two hinder segments, the meso*- and meta*-thorax. The development of the thorax is not surprising, for there must be abundant space within for the muscles which move the organs for walking and for flight. There is little trace of wings in the caterpillar, so that the formation of these organs —as is mainly the case with the legs—may be

said to occur during the pupal period of rest. It follows that the great enlargement of the thorax as seen in the perfect insect does not generally take place until the chrysalis life has progressed.

The wonderful and delicate organ called a wing is, to all appearances, composed of a simple membrane.* In reality it is double; and between the two tissues a multitude of minute air-vessels ramify through every part, accompanied by canals or passages for the circulatory fluids. Immediately after the assumption of the perfect state these tracheæ become solidified like the rest of the skeleton. They are hollow for the reception of air, and afford strength and lightness to the wings, the motions of which are intimately connected with the function of respiration. The membranes are continuous with and expanded portions of the common tegument* of the sides of the segments of the thorax. Their surfaces may be transparent, or coated with dusty scales of microscopic size. The distribution of the contained tracheæ, or neuration,* and the appendages, though of the highest intrinsic interest, are outside the present subject.

The abdomen,* the third division of the body of an insect, is the seat of the greater part of the digestive organs, the respiratory and circulatory, and the generative systems.

The head of some larvæ, like the rest of the divisions of the body, is covered with soft flexible

skin. Usually it is rounded or oval in form and of harder texture than the other segments. Three great pairs of attached organs, the mouth organs, are situated at its inferior surface, and at the lateral and anterior surfaces it carries the rudiments of antennæ,* or feelers, and the eyes where they are present. In the perfect insect, the number and position of these parts are precisely similar. It is only in a manner true to say that the head of an insect is composed of one segment. For though at the birth of the larva no satisfactory separation of this portion into segments can be detected, it is a fact that it, like the other regions, is made up of several rings. The exact number which enter into its composition has not yet been made absolutely clear. Probably the head appendages which form part of the organs of manducation are the proper articulated members of distinct rings, and are analogous to those which constitute the locomotive organs of the body. Since each pair of the latter is attached to a particular segment, in the same manner it may be presumed that the mouth-parts were attached, indicating an early separation of the head * into three segments. Probably there were four, and perhaps five. In many larvæ a projecting papilla, the spinneret, is situated within the mouth. It opens into the glands that secrete the silken material with which the owner spins its cocoon, and performs similar tasks. It is an organ — its func-

tion being no longer needed — that dies ere the insect reaches its perfect stage. While still in the glands, silk is a thickish viscous * fluid. When about to make use of it the larva places the spinneret in contact with some object, and quickly withdraws it, at the same time exuding a drop. The silk immediately hardens on exposure to the air, and is drawn out into threads equally remarkable for fineness as for strength.

In the perfect state of insects the skin may be tough and thick, but still flexible; while in the case of the beetle it is so dense and hard as to appear like horn. But though the variation is great, this tissue is invariably composed of a peculiar substance called chitine. It is formed of two layers, an inner one which is soft, and not made up of chitine — the true skin; the other is external and superficial — the epidermis,* which is capable of becoming hard and horny. Both are intimately connected. It is the epidermis that is cast at the transformations. From its inner layers the new skin is developed, and peels away as it were from the outer ones, when the latter soon dry and become shrivelled and are thrown off, and the new skin eventually clothes itself with a fresh epidermis. Newport infers that chitine,* the basis of the insect skeleton, is intermediate in its chemical condition between the bony and dermal structures. In other words, it is bony matter imperfectly developed, so modified that while it

affords the animal strength and solidity, it at the same time admits of the performance of all the organic functions of the true skin. And it may be that its exuviation * is due not only to the continuous growth of the insect, which causes the body to become too large for the covering to contain, but to changes in the actual condition of the skeleton * itself, dependent upon the same laws of existence which regulate the removal of the old and the deposition of new matter in the bones and other structures of vertebrates.[1]

The modifications of the outsides are not more remarkable than the changes that take place in the internal organs during progressive development. Many persons do not think that a larva has any internal organs at all. They hold the opinion of the gentleman who once confessed his belief to the well-known naturalist, the late Mr. Wood, that a caterpillar is "nothing but skin and squash." In fact, larvæ live only for eating, so that their inward arrangements consist almost entirely of the digestive system, which in many is scarcely more than an elongated tube or sac very much dilated, serving as a most capacious stomach. As such it exists in the apodous * larvæ of some of the bee family. In other members of the order it is more complicated, and it would be possible to go through a list of larvæ whose digestive organs gradually rise in the scale of impor-

[1] Newport.

tance, until they become fairly developed and the simple tube begins to assume the intricacies that it possesses in perfect insects. Turning to the latter, the form of the system is not more indicatory of the habits of the species than in larvæ. Regarding it in a general way, the alimentary canal becomes a long convoluted organ, and shows certain swellings and constrictions, which mark its division into several compartments. Each exhibits distinct difference of texture and is adapted to peculiar function, though all are subservient to the one end, the assimilation of food into matter fitted for nutrition.* New structures are likewise added of which formerly there was no appearance. Taking the principal parts of the tube in their order of succession from the mouth, with which the digestive structures are continuous, an œsophagus, or gullet, a stomach, and a small and large intestine may be distinguished. Glandular appendages complete the apparatus.

Food passes from the mouth into the gullet, or œsophagus,* a portion of the tube that runs through the thorax in a straight line. In the case of insects that live on fluids it is usually narrow, when the diet is more or less solid it becomes comparatively wide and strong. A dilation of the gullet, called the crop, is often present, where food may be stored for a time previous to digestion. This is a provision common in gross feeders, such as grasshoppers and locusts, and in

those that provide for the wants of their young. From the crop the bee disgorges its gathered honey into the cells of the comb by means of the muscular coats of the reservoir. A valve * cuts off the membranous bag from the true stomach, and must effectually prevent all regurgitation * from the latter into the former. In butterflies, and occasionally in flies, the crop is rather more separated from the gullet, and opens into it by a tube or neck. The stomach, the principal organ of digestion, varies much in length and in size generally. Here the food is mixed with the gastric juice, and is finally converted into chyme, just as in ourselves and the higher animals. As in man, the secretion depends upon the state of the stomach, whether it is filled or not. When the stomach is empty the juice is not secreted, upon the introduction of food the glands secrete actively, and the juice becomes acid. Obviously the secretion must be almost continuous during the lifetime of a larva, which seldom ceases to eat. But as the perfect stage is approached, the glands are atrophied and dwindle away, and sometimes become altogether obscure. Their development is best in animal feeders; in herbivorous insects they are much less conspicuous. The modifications of the intestines are of less consequence than those of the other parts. Salivary glands are situated one on each side of the œsophagus, and provide saliva * to mingle with and lubricate food in the mouth,

and to assist in its digestion. They are largely developed in Lepidopterous larvæ, in which they form the web-spinning apparatus and secrete silk. When the caterpillar has completed its cocoon, and turns to chrysalis, there is no further need of silk. Consequently the glands become small, and their function is altered.

At first sight nothing could be more astonishing than the difference in the nervous system, as regards the size and relative position of its parts, at the various stages of development. A minute examination before and after metamorphoses reveals that it undergoes no perfect alteration of plan. The nervous system of the larva is merely adapted for the imago, and the original design is constant, even in the structures of the most highly elaborated insects. In its simple form, in a vermiform * larva, the system exists in the form of two longitudinal cords, extended from the tail end of the body along the median line of the under-surface, parallel with each other and close together, excepting at their anterior part, where they separate and pass upwards to encircle the gullet between them, re-uniting above it in the head. Each of the cords possesses a series of enlargements, or ganglia, throughout its course, situated at certain distances apart, their number corresponding to the number of the larval segments. They are precisely similar in position in both cords. Though apparently a simple structure, each cord is in reality composed

of two distinct but closely united columns of fibres, placed one upon the other. The under or external column, which is nearest to the exterior of the body, alone bears the ganglia, the upper one, next to the digestive organs, is entirely wanting in knots. These cords together are believed to represent the cerebro-spinal system of vertebrates. The ganglion-less internal column of either cord is probably analogous to the motor nerves of the higher animals, and the external column which is possessed of ganglions,* answers to the sensitive nerves of the vertebrata. Thus the two cords are each composed of a motor and a sensitive column. The double ganglia in the head, situated over the gullet, are the largest, and represent the brain. These and the ganglia previously described regulate the animal life of the insect. The vegetative life beyond will-control is maintained by an off-shoot from the principal nervous structures.

Just as the body segments of the larva coalesce in the perfect insect, so also portions of the nervous structures, the disposition of which is in remarkable relation to the segments, become concentrated to perform the perfected functions of this wondrous system. Instead of the nervous matter being almost equally distributed to every segment, the ganglia of the different segments approach and become aggregated, the cords are shortened and enlarge into fresh trunks, and nerves alter in

position and unite into one bundle, changes that are brought about and rendered necessary by the other changes that take place in the body. This concentration is most marked in insects that undergo complete metamorphoses. The greater proportion of the nervous masses is removed to the head and thorax, apparently as a means of concentrating the energies of these particular regions. In some insects especially, the ganglia are usually aggregated together in certain segments, in the part of the body that is very actively employed. A most curious union and complexity occurs in the distribution of nerves to the wings. These, the most powerful and constantly employed organs, must act not only with energy, but in perfect unison with each other, and hence must be supplied with power from the same centre. The union exists in many insects of rapid or long-continued flight, while in heavy fliers, or those accustomed to exert themselves for but short distances, such combination is absent. The ganglia which form the brain are small in the larva in relation to the size of the head. They increase in the pupa, and attain their full development near the termination of that state. Then the cerebral mass acquires a compact form, it is more uniformly opaque than the other ganglia, and fills up most of the cavity that incloses it.

If the metamorphoses of the nervous structures are wonderful, calling fresh senses and faculties

into play, how shall be characterised the changes that take place in the organs of respiration? There can be no comparison between the feeble respiratory* efforts of a sluggish caterpillar or grub, and the amount of breathing energy of a vigorous and nimble insect. The mode whereby an insect breathes is very different from ours. It does not draw in air through one mouth, neither has it lungs, nor is the fluid answering to blood, which the air has to purify, contained in veins, it bathes the internal system.

When the interior of an insect is carefully investigated, a multitude of the tiniest and most delicate tubes are seen branching to right and left, on one side towards the skin; on the other they are distributed to the middle of the body, they cover the digestive organs, and enter amongst the tissues.* These are air-tubes, known as tracheæ, their duty being to convey the air through every part of the insect. A trachea is a tube formed of two layers of membrane, inclosing between them a spiral convoluted thread. It is kept open by means of the spiral, which is very compressible, so that the amount of air any trachea may contain varies according to circumstances. The outside air gains admission to the tubes through small apertures, or mouths, called spiracles, which are situated generally at regular distances, their number being usually nine on each side of the insect —a pair for the first segment of the thorax, and

one for each of the eight anterior segments of the abdomen. Sometimes, as in the case of fly-maggots, there is only a pair of spiracles, which are placed at the end of the body or near it. These larvæ embed themselves in their nutriment, and would be stifled were they unable to draw in air through the exposed tip of the tail. Spiracles are of many forms of structure. Suffice it to say, they admirably guard the entrances to the tracheæ, and are capable of closing them, preventing the intrusion of foul air and other impurities; this also permits of the retention of large quantities of air in the tubes. The spiracles of the abdomen are always much smaller than those of the thorax, and the posterior * ones, which were very important in the larva, are almost imperforate in the later time of growth. The circumstance arises, probably, from the change that takes place as regards the region of the body in which respiration is principally carried on in the two stages of insects. In the larva it takes place chiefly in the abdomen, in the imago in the thorax. In larvæ the tracheæ are always more diminutive than in perfect insects compared with the size of the individual, and are smallest in the footless larvæ of the bee family, which live long in closed cells.

Some larvæ and pupæ that inhabit the water breathe like fishes by means of branchiæ, or gills, respiring the air which is mechanically mixed with the water. These branchiæ are simply ex-

pansions of the external surface of the body, and, as a rule, are extended outwards from the sides. The insect possesses the voluntary power of moving them at pleasure, and thus effects constant renewal of the water in contact with the organ. They are abundantly supplied with minute ramifications * of the tracheal vessels, which are believed to convey the air that the branchiæ absorb into the main tubes, to be distributed over the whole interior of the body, as in insects that live in the open atmosphere. Branchiæ are of various kinds, but the most common one consists of slender hair-like structures, growing together in tufts, as in the young of the gnat.

All perfect insects, whether they are inhabitants of the air or water, breathe air alone. By the time that this stage is reached, the branchiæ, or other curious adaptations for the larvæ, where they were present, are no longer distinguishable, and spiracles are always developed at a part of the body at which the branchiæ were attached. After metamorphoses, the water-beetle (*Dytiscus*), for example, which leads an amphibious life, has the ordinary spiracles for respiratory purposes; but they are situated on the back, enabling the insect to breathe readily by coming to the surface.

In the larvæ of all insects, the internal respiratory organs, or tracheæ, are simply elongated and ramified tubes. But in adults these tubes suffer certain modifications, becoming dilated into an

immense number of minute vesicles, or sacs,* a development well adapted to meet the exigencies of increased force and activity of habit. It not only allows of most extensive respiration, it enables the insect to alter its specific gravity by enlarging its bulk, rendering it better able to support itself on the wing with little muscular effort. That this is the use of the sacs may be inferred from their entire absence in larvæ, and in insects that are not addicted to forsake the ground; while they are largest and most numerous in volants having the longest and most powerful flight. It would be impossible to exaggerate the advantage of this beautiful provision to the humble-bee, which is compelled to be constantly on the wing. Its large and cumbrous body is fitted for all purposes of strength, but would undoubtedly occasion it inconvenience and fatigue, were the apparently unwieldy structures not lightened in this remarkable manner. The development of the vesicles begins at about the period when the larva ceases to feed, preparatory to change to pupa. When an insect is quiet, or is walking, it breathes slowly, and there is little air in the tracheæ. The body is heavy, and must contain more air before the creature can fly. Its act of respiration at this moment resembles that of birds under the same circumstances. It elevates its elytra, the anterior* pairs of spiracles are opened, and the air rushing into them, is extended over all the vesicles. The air-bags expand, which

increases the bulk of the body, rendering it light in relation to the bulk of air it replaces, so that when the spiracles are closed at the instant the insect makes the first stroke with its wings, it is able to rise, and endure sustained and forcible flight without excess of exertion. Explanation is here obtained of the long and elevated voyages undertaken by hordes of locusts, which are not conspicuous for their lightness or over-activity. The muscular efforts of prolonged flight also heighten the animal temperature, and this tends to rarefy the air contained in the vesicles and tracheæ.

The question still naturally presents itself: Why do insects undergo metamorphoses? Why should they, in attaining to maturity, pass through such remarkable development? and Why should the course of development be apparently separated into three or four distinct states, by marked alteration in form?

In the first place it must be observed that most of the animal creation, of the higher classes at any rate, have equally to submit to metamorphoses, or in other words to difference in shape and appearance, and also in structure of internal organs, in their early life and in maturity. Thus many animals which when mature differ widely, show points of resemblance to one another in their young state. Besides, the embryo of every organism is believed to portray, more or less completely, the

form and structure of its less modified progenitors, so that the changes of a single individual as it were exhibit in miniature, and in short space of time, organic evolution in general, which ages of indefinite duration have been requisite to bring about. In fact the great majority of animals do undergo well-marked metamorphoses, but often those most pronounced are passed through within the egg, previous to birth, and thus are not revealed, except to the eyes of the curious.[1]

Birth, it must be remembered, is not the beginning of life, but merely a particular stage in the process of development. The condition of the young may be well advanced before this event, or the reverse, birth may occur at an early period of development, and causes for the difference are readily discovered. Thus the apparent total discrepancy between the metamorphoses of insects such as the locust or grasshopper, and the bee or fly. The two insects first mentioned have become highly developed before birth, the bee and fly have emerged into the world from the egg ere metamorphoses have far progressed. The terms larva stage and pupa stage are therefore somewhat arbitrary, since larvæ at their birth from the egg are in many stages of youthful development.

The metamorphoses of insects depend then first on the fact that the young quit the egg at a more or less immature stage of development. The

[1] Sir John Lubbock. Herbert Spencer.

external forces act upon them in their preparatory state, and are different from those which affect the mature form. Consequently it need cause us no surprise to find that larvæ and pupæ undergo changes which have reference to their immediate wants, rather than to the condition which they will ultimately assume.

As to the second part of our subject: the apparent separation of the development of insects into distinct stages. There is this remarkable point to be observed, that whereas the alterations in many animals go on so ceaselessly and so slowly that we fail to perceive them, in insects the changes appear to be excessively sudden. This does not apply to Orthoptera and others which undergo incomplete metamorphoses, whose development from birth to mature life is gradual and not violent and great. But leaving these cases out of the question, the fact remains that an insect's life is generally apparently divisible into four well-marked states, and the change from the one to the other appears to be quite abrupt. In reality the metamorphoses of insects, like those of all other animals, are continuous. The whole alteration, from the egg to the caterpillar, to the pupa, and from this to the perfect insect, proceeds gradually, and the striking changes in outward form, which take place from time to time and very rapidly, are simply due to a throwing off of the outer skin—revealing a creature which, far from being new, has

been in preparation for days; sometimes for months.[1]

The skin of an insect is very different from our own and from that of other vertebrate animals. It serves in place of a bony skeleton, and is more or less hard because to it the muscles are attached. When it is once made it cannot be altered, and consequently no change of form is possible without a cast of skin. In the case of many larvæ the moultings are necessitated principally by growth and increase in size; the alterations of structure are confined to the two last and more important skin-sheddings. Thus, then, the apparent abruptness of the changes of insects is to be attributed, in great measure, to the peculiar nature of their skin.

That material change of form is often delayed until towards the latter end of development, or until the period of pupa, may be accounted for partly by the structure of the mouth. That of the caterpillar is provided with jaws, fitted for eating leaves, whereas the mouth of the butterfly is suctorial, and capable only of sucking the nectar from flowers. It is clear that were the mouth of the larva metamorphosed into that of the perfect insect by a series of small changes, the insect in the meanwhile would be unable to feed, and must die of starvation in the midst of plenty. In insects like the locust, whose changes are gradual, the mouth of the so-called larva resembles that of the perfect form.

[1] Sir John Lubbock.

No doubt to this change in the mouth-parts, and to the similarly rapid and extensive alterations going on in the pupa, is to be attributed the strange, and otherwise incomprehensible, immobility of this remarkable period. Not only, as in that of a butterfly, the mouth is in a state of transition, the digestive organs and the important muscles, and even the nervous system, are in course of rapid change. It must not be forgotten that all insects are inactive for a longer or shorter time after each moult. The period of inaction varies, being short as a rule when the change is slight, and becomes correspondingly prolonged as the change increases in magnitude. The quiescence of the pupa is therefore not a condition peculiar to this stage, but an exaggeration of the rest that has succeeded every previous change of skin.[1]

[1] Sir John Lubbock.

CHAPTER II

FOOD OF INSECTS

Chief sources of food — Almost limitless choice from vegetable world — Death's Head Moth as a thief — Animal-feeders — Parasitic Hymenoptera and others — Mighty business of insect-parasites upon insects — Larva of the Tabby — Another strange food of animal derivation — Ants and their aphides — Intimate connection of ants with other insects — Usual restriction of insects to vegetable or animal diet — Change of diet at different stages of life — Need of nurses by the young of the Social Hymenoptera — Livelihood without industry — Slave-makers — Honey-ant — Analogy between its economy and that of bee in storage of food — Harvesting ants in the East, in Europe, in America — Time of feeding — Instruments of nutrition — High adaptation of Lepidoptera to floral diet — Means of procuring food — Stratagem of ant-lion.

LIKE the rest of living creatures, insects derive their nourishment chiefly from the animal and vegetable kingdoms, but they enjoy peculiar advantage over others, in that while the larger animals are more or less restricted in choice, as regards the vegetable kingdom especially, the bill of fare presented by nature to our little subjects is practically almost without limit. From the mighty banyan tree of India, covering acres with its stems and foliage, down to the tiny fungus scarcely

visible to the naked eye, perhaps not a single plant exists which does not furnish forth delicious eating to some one of the vast tribes of insects. How different it is with the more imposing beings! To them a considerable amount of vegetation is absolutely poisonous — the acrid euphorbias, the henbane, hemlock, and deadly nightshade, and a still greater proportion, if it is not actually injurious, is so distasteful as to be seldom or never utilised. The common nettle is by no means highly esteemed by ourselves or by the higher animals in general, yet it is all-important to insects, since it sustains the life, so at least it has been computed, of no fewer than thirty distinct species; and the cabbage, while it is serviceable enough in its way to man, is of inestimable value to insects, which to the number of two hundred kinds feed upon its substance, or upon insect vegetarians that indulge in this diet.

The larger herbivorous animals have to remain content with certain parts of plants. They can subsist upon the leaves, the seeds, the fruits, occasionally on the tender stems and roots; the flowers are attacked rarely, the woody trunks of trees never; but to insects no portion could be named that ever comes amiss. Not that insects are indiscriminate feeders, generally speaking; far from it. Many are restricted to one particular sort of plant, and having fed for a time on it, will die rather than partake of change, and their size is such that

they can select a special portion with the utmost nicety. Among those that appreciate the roots and stems, some confine themselves solely to the outer bark; the elm-tree beetle (*Scolytus*) burrows mainly in the inner and softer layers, the goat-moth caterpillar penetrates to the living wood, and others, as the beetle that infests the pine, bore into the central pith of young shoots, doing incalculable injury to pine plantations. To turn to those whose preference is for leaves and leaf-blades, the plant-lice, or aphides as they are called, imbibe alone the juice or sap; a large number of the young of tiny beetles, flies, and moths taste solely the cellular substance, or parenchyma,* disdaining the tough skin or cuticle as being much too gross for their delicate appetites; at times only the lower surface of leaves is eaten; while caterpillars as a rule are far from dainty, and demolish leaves whole and entire. With respect to insects addicted to flowers, the earwigs and thrips, for example, choose the beautiful coloured petals; some select the pollen; and an innumerable host — moths and butterflies, bees, ants, flies, and many more — make any effort to obtain the honey, that especial delicacy secreted in the nectaries. The Death's Head Moth is excessively fond of it, and enters the hives of bees, knowing in some astonishing way that honey is to be had there. Oddly enough, the bees do not rush upon the intruder and thief, but use every artifice in their power to exclude it, or to wall it up.

Nor are insects restricted to vegetables in their fresh or unmanufactured state. They will secure their livelihood from a piece of furniture, or from the woodwork of buildings hundreds of years of age; they even feast upon what one would imagine had surely been robbed of all sweetness and succulence—the dried flowers of a botanist's collection. Nevertheless their bodies are often as well stocked with fluids as are leaf-fed caterpillars.

Insects that feed on animals can boast of a diversity of food nearly equally great. While the Sexton, or burying beetles favour dead carcases, the majority are adapted for living prey. A class of these, the parasites,* form one of the most curious and interesting phases of all methods of insect life. There are the Strepsiptera, parasitic throughout their lifetime upon bees and wasps. There are the gad-flies, which, as adults, pierce the skin of cattle and horses, maybe of ourselves, and suck the blood. There are the young of various bot-flies that insinuate themselves beneath the hide of the ox, or deer, or goat, and procure regalement in the swelling caused by the irritation produced. They likewise penetrate into the nostrils and head of sheep, and the stomach of the horse or cattle, being carried thither by the tongue of the animal in licking its coat, whereon the insect mother had previously laid her eggs. The mites, and ticks, and fleas infesting animals and birds need not be more than mentioned. Numerous flesh-feeders kill

their prey outright. They devour either its solid parts, or merely drink in its juices, rejecting the dry frame.

The subject of insect parasitism upon insects is a very fascinating one, but for want of space it is impossible to linger long upon it here. Unfortunately, anything like an adequate conception of the absorbing interest of the study cannot be gained by a briet notice. The leading parasitic families of the order inclusive of the bees (Hymenoptera) constitute a little world by themselves, but though their numbers are enormous, all alike are guided by the same general habits and instincts. Few insects, if any, are exempt from their attacks. Usually the female seeks out a caterpillar, a larva, or insect suited to her purpose, and lays her eggs in or on its body, and the larvæ that are born of these eggs feed upon the fatty tissues of their host, leaving its vital organs for a time uninjured, for were the host to die the parasites could not survive. The internal parts of the victim are not devoured until the parasitic larvæ are nearly full-grown and fed, and ready to change into pupæ, when a prolongation of the life of the unfortunate creature is unnecessary. In some cases the victim, should it be a caterpillar, continues to feed and live as though nothing were amiss subsequent to its reception of its unwelcome guests. It may even manage to turn to chrysalis; but it never attains to the perfect form, when it could lay eggs

and reproduce its kind, because invariably ere it reaches the final stage the maturing larvæ it contains have destroyed it, by a slow but sure consumption. Thus it often happens to a butterfly collector who has been looking forward to see a fine butterfly emerge from its chrysalis, to be disappointed, and to feel chagrin, by the appearance of several little parasitic Hymenoptera,* which, unknown to him, the butterfly has all along been sustaining, and to whom it has at last been compelled to yield up its life.

When a parasite in open day finds an insect that will answer admirably as the nourishment for her future larvæ, and deposits an egg in it, the act does not involve any marked degree of cleverness, nor is it difficult to comprehend. But by what power does she become aware of the presence of a suitable host inside fruit or the branch of a tree, and completely concealed from sight? She discovers the exact spot where it lies hid, and, with her long ovipositor,* pierces through the bark, or solid wood, or skin, as the occasion requires, driving her eggs into closest contact with the selected victim. When one ability fails to be useful under the circumstances of life, another is believed to come into prominence to supply its place. Her eyes * cannot assist her to this knowledge, which has been attributed to the sense of smell, aided perhaps by that of hearing, but these matters await elucidation. The mother's capacity, as it were, to gauge

the appetites of her young is equally extraordinary — creatures of which she can know nothing. She is no miserly caterer, but is ever careful to provide them with nourishment in quantity enough and to spare. A large parasite lays only a single egg at a time, because its larva is capable of consuming the recipient's entire substance; had it been accompanied by brother-larvæ, they must all have come to grief by starvation. If a somewhat smaller parasite avails itself of a great host, then two or three eggs are introduced; and should the ichneumon* be very diminutive, the host may receive as many as fifty or sixty, or more. But these insects seem incapable of altering their proceedings according to the occurrence of events. Each follows the same plan for generation after generation, without variation. If a large parasite came across a bigger host than it had ever met before, it would bestow only a single egg upon it, and a small parasite would always lay prolifically, whatever might be the size of the receiver detected.

Sometimes parasitic larvæ are so excessively minute as to find accommodation and nourishment in the eggs of insects. Those of many Lepidoptera, of a small beetle and of the dragon-fly are thus destroyed. Pupæ are also invaded, as well as imagos. Of all the conditions, however, that of the grub or larva is principally liable to these terrible attentions, because it is often the one of longest duration, and therefore best calculated to

carry out the object of the parasite; whereas the adult, and chrysalis, and egg stages are in many instances brief, and more likely, the first and last especially, to be cut short by accident. Strange to say, insects which have long adult life are subject to parasites, whilst those to whom an ephemeral career is meted out go free. Weevils are long-lived, and though encased in what would seem impenetrable armour, and able to withstand the assaults of many a large and open foe, they are pervious to the lancet-like sting of the indefatigable and more insidious assailants.

These parasites have a mighty business in the world, being the means employed by nature to keep within due bounds the superabundant multiplication of the phytophagous, or vegetable-feeding, insects, which would often increase to an unwarrantable extent, and do infinite mischief were it not for these appointed checks. They perform a marvellous work to our advantage, which is the more evident when we consider them in relation to insects injurious to the crops. They afford a wonderfully great protection from those most troublesome pests, one in a sense superior to all the artificial methods of prevention that were ever devised, inasmuch as they cost us absolutely no trouble and no expense. The balance of life between vegetables, insect pests, and their parasites is indeed extraordinary, and we cannot be too careful of instituting measures tending

to upset, even ever so little, nature's appointed ways.

Not only animals themselves, animal matters in great variety constitute the food of many insects. Hair, wool, leather, silk, fur, even feathers, are not despised, and the grub of a beetle, with powers of digestion that a dyspeptic might envy, can subsist on horn. The larva of a moth popularly styled the Tabby (*Aglossa pinguinalis*), known both in houses and stables, has the still more remarkable fancy for grease in any shape or form — for greasy horse-cloths, kitchen fat, and so on — and nothing could be more interesting and instructive than the marked adaptation of its structures for the mode of life it adopts. Its habit is to feed by diving into the food-stuffs bodily. It is in no danger of being suffocated, for its breathing apparatus is arranged to prevent the fat from clogging its pores. Kitchen fat and horse-cloths are products of a more or less recent civilisation, and probably no one will deny that these larvæ have acquired their peculiarities, enabling them to obtain food under such extraordinary conditions, at a period subsequent to the introduction of the fatty materials in question. In a word the moths are a new species, evolved from ancestors which led different lives. To reject this opinion is to believe in their special creation for the purpose of relieving the world of a little superfluous fat. Another set of caterpillars (*Galleridæ*) have a strange liking for wax, and to

gain this substance force their way into beehives and the homes of wild bees, protecting themselves from the revenge of the lawful owners of the nests by spinning silken web around them in the cells of the combs,— robbers comparable with the Death's Head Moth.

Ants indulge in a far stranger food of animal derivation — a sweet liquid produced by insects — and often abstract it direct, warm so to speak, from the living body. The suppliers are aphides, or, according to their popular appellation, the plant lice or green fly, unhappily too well known in every flower and kitchen garden. On roses, geraniums, beans, cabbage, and fruit trees they multiply amazingly, and suck away the richest of the vegetable juices by means of a rostrum or tube, sometimes of great length, with which they are provided. Careful examination of a plant crowded with aphides seldom fails to reveal the presence of an ant, and it is not by chance that this member of the "little people" has wandered into the midst of the alien assembly. It has come with deliberate intention, to feast off a dainty and luscious meal, a sugary, limpid, viscous secretion which is now and then exuded by the aphides, and denominated honey-dew. Ants, as a rule, do not wait to obtain it on the yielder's pleasure. One may be seen to approach an aphide, the extremity of whose body it rubs gently but rapidly with its antennæ,* as if to entice the insect to accede to some request.

The caress has the desired effect, for the aphide responds to the call by ejecting a drop of liquid which the ant greedily laps up; the aphide in fact acts as the ant's cow. No use of the secretion to the aphides themselves has been recognised; probably, since it is sticky, it is to their advantage to have it removed. This liquor forms the principal nourishment of many ants, of the red and yellow kinds in particular, the different species of ants being chiefly devoted to different species of aphis.

Towards the aphides of their choice ants extend special guardianship and protection, treating them as their own private property, and resenting on part of them all interference offered by other insects. Some take possession of a branch where their cattle browse, and hold it against intruders by vigorously attacking any aggressor. They serve as an efficient standing army to the aphides in return for the food that the latter furnish. Some ants build little walls of earth over their aphides, cow-sheds they may be called, to prevent them straying. Some form a private covered roadway between their cattle's grazing ground and their nest, placing their cows within easy reach and distance of communication. Others of these ingenious beings, who are always busy, have taken to heart the lesson of the necessity of the economy of time and labour. To save themselves repeated and tiresome journeyings to and fro, they frequently thoroughly domesticate their cows, so to speak, or

drive them in considerable flocks into the near neighbourhood of home; sometimes they convey them inside their nest. The aphides selected feed on the sap of grass and roots, a nutriment that lies ready to hand without troubling the captives to step out of doors, the subterranean chambers and corridors being constructed in the midst of the vegetation required. Formica show themselves good and attentive masters, and use their aphides with unvarying kindness and consideration.

Ants actually breed their cattle, rearing them through the different stages of existence, hatching them out as though they were their own with the utmost care and tenderness. A fact has been discovered by Sir John Lubbock in connection with this habit, which he describes as one of the most remarkable he knows in the whole history of animal life. Certain aphides live not in an ants' nest, but outside on the leaf-stalks of plants. The wise and judicious cattle-breeders do not think of allowing the eggs laid by the aphides in the autumn to remain exposed to the severity of the approaching winter and innumerable dangers. They collect them and bring them into their nest, and the young are tended and fed and kept from harm by the ants until the following spring, when they are carried again to the food-plants on which they were at first deposited. During all this period of watchful superintendence the aphides are not of the slightest use to their attendants, who receive

no immediate return for their services. They lavish this care upon these insects with the expectation of future payment, in order to have a fresh stock of aphides in the spring. In this way they secure adequate supplies of sweet liquid food, an instance of prudence and foresight unparalleled in the annals of the animal world.

Ants go similarly in search of the cocci * or scale insects, among them the valuable cochineal, and several Homoptera,* such as Membracis and its allies; they are also intimately connected with a large variety of beetles. Many of these, like the aphides, live habitually with the ants; at least between thirty and forty different kinds of beetles are rarely, if ever, met with excepting in ants' nests. The reasons for the retention of these normal boarders are unknown. Many most curious functions have been assigned to them, but a considerable proportion of the co-habitants of the nest are in reality ant-cows. Claviger beetles at the base of their elytra possess tufts of tubular hairs which the ants take into their mouths and lick, and also the whole of the upper surface of the beetle's body, doubtless abstracting some special secretion that affords satisfaction to their palate. In return, the beetles are believed to be maintained at the expense of their grateful hosts. One quaint little claviger is blind, and is apparently quite a dependent, having lost the faculty of feeding; at any rate it has never been seen to take

refreshment alone, this is invariably administered by the nursing ants.

For the most part, insects that feed on vegetables will not touch animal matters, and *vice versâ*, but the rule is open to exception, notably as regards ants. Many caterpillars, though plants are their proper food, will occasionally exhibit depravity of taste, and if kept with their own kind, or with the larvæ of other moths, may turn cannibal, and make away with the company. Similarly, the large green grasshopper will eat insects smaller than itself as well as its ordinary vegetable diet. The same may be said of young caddis flies, and of the mole cricket, which burrows in the earth, and feasts on roots. Should it meet a worm, or an insect, on its travels, it seems to see no reason to deny itself a little variation in its customary provision as a relief to sameness. On the other hand, some carnivorous beetles will make a hearty meal off a putrid fungus. One small family of this order (Dermestidæ) in the larval state is a veritable plague in museums, attacking furs, skins, and dried flesh, and is not disinclined to enjoy bacon and ham. In the event of being unable to obtain anything of this sort, it has been known to pounce upon and ruin a ship's cargo of cork.

It is a very remarkable fact that insects frequently change their diet completely at their different stages of existence. Moths and butterflies in their immature condition feed on leaves and twigs,

in the interior of trunks of trees, in roots, in seeds, or in the insides of fruits; while none when mature deigns to partake of anything stronger than a fluid, generally obtained by a casual choice and gentle sip from the honey-bearing cup of a lovely flower. In some parts of the world in the case of flowers wanting in the secretion of free honey, these insects tear open the delicate succulent tissues in order to get at the sap; they rifle the juice from fruits, such as plums, peaches, and oranges, in like fashion. A greater change holds good for the various states of the Hymenoptera or Bee Family. As imagos they are usually strict vegetarians, but during their larval period, while some live on plants — the bees, sawflies, and others — many are absolutely carnivorous, and can exist only upon living prey.

It is customary for insects to provide for their own wants. A mother forsakes her young, leaving them to get on as they best may, but she takes care to deposit them in a spot in the midst of sustenance, or where it may be readily procured by the larvæ. Sometimes she goes on foraging expeditions, and stocks the larder of her infants with nourishment, whether of a vegetable or an animal nature, sufficient for their consumption until they reach maturity. Some young, however, are incapable of feeding without assistance. They require a staff of nurses to watch over them day by day, who are industrious and patient enough,

and qualified by intelligence to rear their troublesome charges through their early helpless stages. The young of ants, of bees, and wasps, that live in societies, are thus dependent upon their elder relations. The mouths of the ants are small and ill-developed, possessing two tiny hooklets, perhaps the embryos of the future mandibles,* but far apart from each other and of little use. The larvæ themselves are too feeble to move and seize the food were it placed within their reach. But they have the instinct to lift their heads and gape like birds new-hatched to receive their meals from their guardian's jaws, being directed so to do by a tap from the latter's antennæ. The aliment administered is believed to be in accordance with the age and sex, the females in all probability being furnished with greater liberality, and with stuff of a peculiarly stimulating nature. From the enormous number of mouths waiting to be fed in a well-filled ants' nest, day by day and several times a day, some notion may be formed of the severity of the duties — and nursing constitutes merely a fraction of them — so successfully undergone by the unselfish and untiring "workers," and we cease to wonder that they display the activity which is so conspicuously a trait of their char-

Fig. 3. — A honey-bearing ant (*Myrmecocystus Mexicanus*) regurgitating honey from her crop at the solicitation of hungry workers; from McCook.

acter. Even when the period of infancy is passed, and the pupa is extracted from its silken shroud and emerges perfect, nourishment is again given to the new-born nursling by the nurses, who likewise introduce the unused inmate to the common home and work. Not only the young of the nest receive attention. The foragers on their return home gorged, deliver up a portion of the plunder to their less fortunate "grown-up" friends, whom indoor business has compelled to remain at home.

The above remarks apply almost equally well to the feeding of the young of social bees, which differ in this respect from ants, that they dwell generally coiled up within narrow cells. Probably the bees who particularly assume the function of nurses are recruited from the ranks of the workers who are only recently released from their pupal bonds. Possibly the oldest workers of the hive are likewise deputed to this occupation, in consequence of their growing inability for the more onerous and arduous labours of building and of gathering and carrying home honey. The larvæ of wasps are somewhat more hardy than those of bees, their head is larger and of greater strength, and the mouth is stouter. They therefore receive occasional bits of fruit and fragments of insects in addition to the usual fluid, or very soft nutriment, upon which alone ants and bees are bred.

The young of solitary bees and wasps are able to take their nourishment unaided if it be placed

beside them. But the mothers of certain species cannot make such provision, being deficient in the structures necessary to enable them to build and collect the proper food. They therefore use their wits instead of labouring, and introduce their eggs into a nest that is already victualled by some industrious Hymenoptera for its own progeny. The usurping larvæ are hatched sooner than the rightful inheritors of the home, and utilise the nutriment that surrounds them without care for the sorry plight of their defrauded companions.

Some kinds of ants are similarly helpless. Their difficulty is very great, for ant-larvæ must be fed from the mouths of nurses. The method of cutting this gordian knot of perplexity comprises one of the most curious and extraordinary phases of the many-sided ant character. It is a marvellous imitation of the ways of man. They make regular periodic raids and forays upon the nests of other ants and carry off their workers, training and subjecting them to undertake the offices in which they cannot themselves engage. The adults of the foreign colonies are not seized, because they would never become domesticated in a strange home; it is their larvæ and pupæ that are taken. When the captives reach maturity, they appear to make no attempt at insubordination or escape, but at once assume the duties for which they were enlisted. These warlike ants belong to the genus *Polyergus*. They are a striking instance of the

degrading effects of slavery, for they are not only dependent as regards the care of their young, they have lost almost every instinct and power that they ever possessed, and, as a rule, all building operations and all foraging for food likewise devolve on the slaves. The masters will not even "do" for themselves, they are waited on, fed, and cleansed by their willing serfs. In the event of change of the domicile, the servants remove their masters along with the young to the new abode. But the *Polyergyes* continue to be warriors, and remain capable of capturing fresh bondsmen. In other species of ants the distinction of the relative position of the masters and servitors is considerably relaxed. The latter are merely introduced into the nest of their captors to assist in the various departments of labour; all alike mingle freely together and share in the common work of the colony. In one species of ant, *F. sanguinea*, this slave-making propensity has been observed in active exercise in England.

Social bees, as is well known, lay in provision in the cells of the comb that they fashion within their nest. It serves for themselves and their young for a rainy day and for winter need. The provident habit is usually denied to the wasps and to the third member of the trio of communal Hymenoptera, the ants, which are believed to live from day to day from hand to mouth. It would be almost superfluous for ants to store food, it is

commonly asserted, since, like most insects, they become stupid and hybernate so long as the cold months last. Whether this generally received opinion is altogether correct remains to be seen.

A native ant of Mexico (*Myrmecocystus Mexicanus*) has recently been found plentiful in that section of the country known as the Garden of the Gods, Colorado, by the naturalist Dr. McCook. Early in life certain numbers of its workers begin to show unusual distension of the abdomen, gradually increasing as time goes on, until this part of the body assumes prodigious proportions in comparison with the upper portion, the head and the legs. In perfect cases it varies from the size of a large currant to that of a tiny grape; its appearance resembles a transparent bubble. The external covering membrane of this globe of tissue is excessively thin, and one can see what is contained inside. The inflation is due to a great accumulation of syrupy-like liquid, which is sometimes whitish in colour, more commonly of an amber shade. These ants are the living cells or storehouses of food for the community. A complete analogy may be established between the economy of this remarkable structure and habit and that of the bee in the storage of honey within the comb. The rotund ants do not elaborate the secretion, they are charged with it by those workers which are honey gatherers, who, when they return to the nest after absence on a foraging expedition, give up their

collected supplies to the distending individuals, who more or less entirely remain at home. They do this by means of regurgitation, and by injecting it into the mouth of their wonderful sister formicarians. Within the latter the honey is held in reserve in case of emergencies, such as the seasons when the gleanings are less abundant or when the resources of nature wholly fail. Notwithstanding these disasters the family must be fed; and be it remembered that many of its members — the queen, the virgin females, the males, and the occupants of the teeming nurseries — all look to the workers to supply them with food. Just as under similar circumstances the bee goes to the honeycomb, breaks open a waxen cell and abstracts the contained sweets, so the worker ants go to their companion honeypots when they are hungry or if desirous of administering nourishment to others. The bearer from its store delivers up the honey required, the pensioners lapping it from off the giver's lips as it gathers there, being forced up in little drops or globules by the muscles of the abdomen. (See Fig. 3.)

These remarkable ants live in dwellings underground, and the honey-bearers may be seen in chambers set apart, in little rows, clinging by their feet to the ceiling, their sphere-like abdomens hanging downwards. (See Fig. 4.) Though it is a mistake to deny these unhappy gorged creatures the power to move, and to abandon a perch after it is

adopted, there can be no doubt that movement and change of posture are less and less resorted to as expansion increases, and when a well-filled individual loses its grasp and falls to the floor, it is generally incompetent to recover its balance. To a certain extent the workers evidently regard them as dependents, the light in which they probably look upon the other members of the hive. They even perform their toilet for them, though the rotunds seem able to assist themselves.

The outer wall of an ant's abdomen consists of a series of chitinous segmental plates, ten in number, five dorsal * and five ventral * ones, which overlap one another like the tiles of a roof. These plates alone are visible externally in an ordinary ant. In all ants, however, they are laid upon (if I may so speak) an inner coat, which is highly elastic, and in ordinary excessive feeding this membrane is stretched between the plates, forcing them apart, the degree of separation varying with the amount of food taken. In the case of the honey-bearers some of the plates become isolated, appearing like little brown transverse bars on the tersely-stretched and lighter coloured wall. Dr. McCook supposes the honey to be not contained within the stomach, but in the crop, an abdominal portion of the œsophagus. The result is that the crop becomes immensely distended, and almost completely fills the cavity of the abdomen, to the displacement of the stomach and other digestive organs, which are

pushed into small space towards the anal extremity. Sir John Lubbock mentions another species of honey-ant, which he describes as *Camponotus inflatus*, from Adelaide, Australia. In it a similar habit and modification have been evolved. Since the rotunds are probably developed from the ordinary worker and do not comprise a distinct caste, the possibilities of such enlargement may exist in the structure and functions of all honey-feeding ants.

The Indians and Mexicans eat this honey freely, and not unusually the ants are served at table as a dainty morsel, the head and thorax being removed. The liquid is also pressed out of the body, and forms the principal ingredient of an exhilarating drink somewhat like mead. It is supposed to possess wonderful healing properties, and has a place among the native remedies for disease, being applied to bruises, to swelling, and as an unguent to cataract of the eye. That it might ever become of practical commercial value is hopeless, since the comparative number of workers being honey-bearers in a nest is strangely small.

The opinion of many eminent naturalists of the present centuries is opposed to the belief that ants show foresight and husbandry in the systematic collection and storage of seed. Ancient books, both Oriental and European, show their writers to have been quite at variance with the modern idea. The authors of neither period are altogether in the

right. It is a mistake to deny the seed-storing habit to any ants, an error that arises from too hasty generalisation and limited observation. To attribute it to ants in general, irrespective of species or country, is equally incorrect, the ancients having judged from their own circumscribed experience and the reports of others. The truth is that the harvesting of grain by ants does occur, but seems to be confined to a small number of kinds, and to tropical and warm climates. Research is bringing to light the very interesting fact that as a rule in those countries where the ancients lived and wrote, the harvesters abound to the present day. Recent investigators have discovered them in India, and, to come a little nearer home, in Syria and Palestine. In the two last countries the insects must have existed in striking abundance in former days, and have amassed stores of grain of sufficient size to make them worth collecting. This is to be inferred from a passage in the Mishna,* being a quaint bit of legislation deciding the property rights to the ant-stores found in fields of corn, whether they should appertain to the gleaners or the proprietor of the field; — the rights of the poor little collectors themselves seem to have been beyond the pale of consideration. We smile at the scrupulousness of a people who could legislate upon such a subject, one of those pitiful *minima* which even the Jewish law might surely have passed by. Nevertheless the edict is an important

one, showing that these operations of the ants were noticeable enough to call for comment.

Nor are harvesting ants entirely absent from the European continent. Two species (*Atta structor* and *barbara*), being true harvesters, were discovered in the south within recent years by the English naturalist Treherne Moggridge. He watched them gather and transport the seeds of a large variety of plants to their nests, and upon excavating the nests at different periods of the year, he found the garnered grain carefully stowed away for future want in subterranean granaries. If seeds be placed in the soil at not too great a depth, and be subjected to the requisite warmth and moisture, they usually do one of two things after an interval of time. Either they germinate or they rot. Those gathered by these ants do not tend to do any of these things. Yet they lie in damp and moist chambers, and have been discovered in genial weather, and often at a trifling distance below the surface. The inference is that the ants prevent the grains from germinating, exerting some influence which checks the inherent power of nature. It has been suggested that the little radicle,* or first-growing rootlet of the future plant, is gnawed away, which would effectually put a stop to germination. The idea seems untenable, for in the case of deserted granaries, or if the ants are restrained from entering their granaries, the seeds begin to sprout, a proof positive that the

power of growth is not destroyed, but merely hindered for a season. The necessity for the action is obvious, for else the seeds would have to be rapidly consumed at stated periods and be frequently renewed.

Of late years harvesting ants have been also observed in America. The agricultural ant of Texas (*Myrmica Atta barbara*) not only stores seeds, especially those of a kind of grass-like rice (*Aristida stricta*), the so-called "ant-rice," it maintains clean disks of ground round the entrance to its nest, a marvellous work considering the size of the labourer, and the rich soil and hot climate. Many of the disks are not perfectly clean, usually round the edge a growth of ant-rice scrupulously free of all weeds is permitted, and the produce of this crop is carefully harvested at the right time of year, an arrangement than which none could be more convenient. Two other ants, the one peculiar to Florida (*Pogonomyrmex crudelis*) and the mound-raising occident of the great American plains (*P. occidentalis*), are likewise believed to be extensive harvesters.

In England as yet, and in countries of the same or of colder temperature, harvesting ants have not been found. Perhaps the difficulties in the way of hoarding seed in good condition in the damp climate of Northern Europe would prove insurmountable. The food of European ants consists chiefly of insects and other small creatures which

would not keep fresh, and of sweet secretions, vegetable and animal. Yet in a way European ants *are* provident, seeing that they can obtain a meal at will from the aphides and other ant-cows that hybernate along with them. Vegetable honey they have not learned to preserve, probably because their young do not need confinement in cells, like

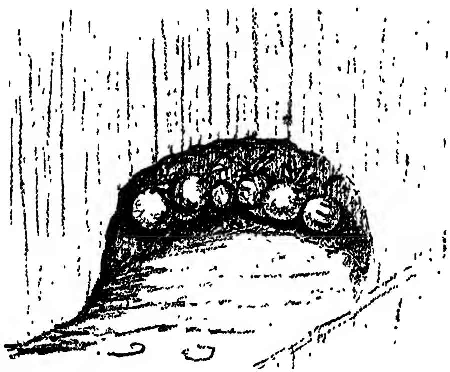

Fig. 4. — View of honey-bearers as seen in natural site clinging to the roof of a honey-room ; from McCook.

the larvæ of the honey-bee. But on the whole the disproved maxim of the uselessness of storage of food by ants holds good of the English species, which succumb to sleep more or less, and require little or no nutriment during the cold winter months.

When the sun is up, and everything is gay and bright, and around all nature seems quivering with

eager motion and activity, we are apt to imagine that we see before us the whole population of the insect world. In reality a multitude as vast shun the glare of day, and, like the votaries of fashion, quit their couch and rouse into thorough wakefulness at the sober hour of twilight, when their more vulgar brethren have retired to rest. The "painted butterfly," the "fervent bees," the "quivering nations" of flies, bask in the sunshine and search for food. But after the sun has sunk many moths emerge from hiding, the shard-born beetle with drowsy hum sallies forth, and numerous others of its kind; and the gnats begin to wing their airy flight, and hunt down their living prey with a bloodthirsty and relentless ferocity, totally at variance with the aspect of things so fragile and so small. Some larvæ too are night-feeders, but to the generality the time for food seems usually a matter of indifference, and they eat apparently with little intermission both night and day.

In manifold variety of form the mouth or feeding apparatus of insects leaves that of all other animals far behind. It differs widely in the various orders, it differs in the families, it does not always remain constant throughout the lifetime of the individual, often there is an absolute dissimilarity between the mouth of the larva and that of the perfect insect. The mouth parts may, however, be broadly divided into two kinds: those made up of mandibles or jaws for comminuting

food, and those forming a haustellum, or instrument for the suction of liquids without distinct manducatory organs. This difference of structure affords a natural opportunity for separating the Insecta * into two great tribes or sections — the Mandibulata and Haustellata, or mandibulate and suctorial groups.

It is possible to reduce the vast differences of the jaws and eating apparatus to a still more elementary basis of structure. From this point of view the mouth of an eating or mandibulate insect is very instructive. Take that of a beetle or grasshopper. It consists chiefly of six parts, of which four are lateral and disposed in pairs, the other two are opposed in the opposite direction, thus :·: There is the labrum, or upper lip; on either side are the first pair of jaws, or mandibles; then come a second pair of jaws, the maxillæ; and finally, below the mouth is a lower lip, or labium, articulate with the chin-piece. The curved articulated appendages with which the maxillæ and labium are externally provided are known respectively as the maxillary and labial palpi. In the jaws of many larvæ, of a caterpillar for example, the form of the mouth-parts is almost precisely identical. The upper lip is well grown, the mandibles are powerful, the lesser maxillæ are present, and behind these is the labium or inferior lip. And as in the beetle and grasshopper when they are perfect, the maxillæ and labium of the imma-

ture caterpillar are in general furnished each with a pair of palpi or feelers.

Let metamorphoses go on, and the leaf-eating caterpillar becomes a sucking butterfly. A more pronounced example of the Haustellata tribe could not be given, and its dainty feeding organs seem to have nothing in common with the coarser apparatus of mandibulate insects, or with the early larval condition of its own mouth. In a butterfly's mouth the only apparent structures are a more or less long slender trunk or tube, and two scale-like feelers or palpi situated below it. By removing the fine hairs and dense clothing of scales from the front of the head, a small transverse lamina * is seen, and its relative position determines it to be none other than the upper lip that was discovered in the caterpillar, although it is marvellously changed since then. Continuing the investigations, a morsel of skin is observed on either side and beneath the lip, and judging, as in the previous instance, by position, the bits of skin are the remnants of the once strong biting mandibles. Beneath these is the conspicuous trunk, bearing at its base two small palpi, the presence of which leaves no room for doubt that the trunk is formed of the altered maxillæ of the caterpillar. Below all is the labium, supporting large instead of the formerly small palpi. Examination thus reveals the fact that the three pairs of mouth-organs of the caterpillar are all present in the

butterfly, though in a very different condition of form.

This wonderful continuity of structure throughout the lifetime of a butterfly, in its change from a mandibulate* larva to a sucking perfect insect, shows that the mouth-apparatus of every insect, of the Haustellata and Mandibulata alike, is founded on the one self-same plan. The best "all-round" or typical development of the head and appendages is to be found in mandibulates, as a whole in the beetle family (Coleoptera). In Haustellata the deviation from the type is enormous, but it consists merely in the modifications of certain parts, which are more or less developed in each order in accordance with the general habits and instincts and modes of life. In mandibulates in the carnivorous and omnivorous families, whose habits require great strength, either in obtaining food or in the construction of their nests, the mandibles are the most important of the oral organs and the most largely developed. In Haustellata, whose food and modes of life are entirely different, the mandibles lose their importance and become atrophied, and their office, now altered in its character, is performed by the maxillæ and labium. The development of these parts is so great that they have become almost or entirely the sole means of taking food, whereas in the higher forms of insects it is only of secondary importance.

The transformations of the structures of the

mouth of bees and flies are quite as wonderful. Into these changes we must not enter. Of the three kinds of insects, in fact of all insects without exception, Lepidoptera hold the highest rank as regards special adaptation to flowers. They take little thought for their young, and the mouth has been free to adapt itself to the easiest possible winning of a floral liquid diet. Many perfect insects have similar tendencies as to food, but have been hampered with additional desires. The adaptation is attained by the astonishing development of the maxillæ, to the almost total abortion * or suppression of the rest of the mouth-parts. The atrophied condition of the now useless organs affords a beautiful illustration of the law that in proportion as the functions of an organ become suspended, or are not required, by the employment of other parts, the organ itself deteriorates and becomes useless, and perhaps entirely disappears.

The maxillæ are modified to take food in a liquid state, and still further the food is produced in extremely inaccessible situations — in the deep hidden chalices or nectaries of flowers. Thus they assume the shape of an elongated, slender, and flexible sucking-tube. Each maxilla is transformed into an immensely long rounded filament,* convex on the outer surface, concave on the inner side, and the tube is formed by the close approximation of the two organs. Throughout almost the entire length of both filaments one or more large tracheal

vessels run, which are connected with the tracheæ of the head. They divide into a number of minute ramifications as they approach the extremity of the organ, but have no communication with the external surface. The presence of these vessels has given rise to the idea that each maxilla is hollow in its interior, for when the tube is cut across — it is best to cut it towards the basal end — it appears to be made up of three small tubes, two lateral ones encompassing a central tube between them. The inner or concave surface of the maxillæ which forms the tube is lined with a very smooth membrane. In some species the extremity of each maxilla is furnished along its anterior and lateral margin with a great number of minute papillæ arranged in two rows; to judge from their structure and other circumstances, they may probably be regarded as organs of taste. Among other curious things the tube possesses some stiff, sharp-pointed appendages along the inner anterior margin of each maxilla, in the shape of hooks of marvellously small size. When the proboscis * is extended they are believed to inosculate with each other, the hooks of the one side with those of the other, just like the dovetailing of joiner's work, and to serve to unite together the two halves, so that they form the anterior surface of the canal.

With this exquisitely simple mechanism butterflies are able to probe to the bottom of the most

variously formed flowers, and to drain their honey. Not even the nectar of the long narrow bells of the Marvel of Peru or of the trumpet-shaped honeysuckle is safe from their pliant trunks, hidden treasure that they could never have had the opportunity of tasting had they retained the short and more primitive biting jaws. In the state of rest the tube is spirally coiled up like the mainspring of a watch in front of the head in small and convenient compass, and lies partly concealed and defended between the labial palps. It can be brought forward in an instant, straightened out, and darted downwards in obedience to the bidding of its owner. In regard to length it varies in the different genera and species, showing all degrees from the proboscis of the Bombycidæ, that take little or no food, in which it is almost imperceptible, to that of *Sphinx ligustri* and the Humming Bird Hawk Moth of South America (*Macroglossa titan*), the trunks of both of which are about two inches long. In butterflies and many of the Noctuidæ they are about the same length as the body. The Sphingidæ are remarkable for not alighting on the flower that they propose to rob, they poise on the wing before it, and rapidly dip into its well-like honeyed cups, without crumpling a petal. Having extracted its sweetest contents, they hasten away on their violent flight to another blossom.

The manner in which the honey is conveyed by the trunk to the mouth has been explained to be

by capillary * attraction. This opinion is probably incorrect, since the ascent of the fluid along the tube is not gradual and regular, as would be the case were it occasioned by this action. The liquid is as it were pumped from the flower, sometimes in full stream for one or two seconds; then the motion falls off and becomes slower and slower, indicating distinct intervals between each draught or ascent of the fluid. The phenomenon appears to be due partly to the undulations and contractions of the sides of the tube occasioned by the action of its transverse muscles, which continue in action so long as the insect is feeding. This agency is assisted in great measure by the lateral canals, or tracheal vessels of the organ. The butterfly at the instant that it alights upon a flower makes a forcible expiratory effort, by which the air is removed both from the tracheæ of the proboscis and from those with which they are connected in the head, and at the moment of applying its proboscis to the food it makes an inspiratory effort, dilating the tube, and the food is carried along it quickly to the mouth to supply the vacuum produced, without any interruption of the function of respiration. By this combined agency of respiration and muscular action, we can understand how a butterfly is enabled to extract in a moment the honey from a flower while hovering over it. This it certainly would be unable to do so rapidly, were the ascent of the fluid depen-

dent on the action of the muscles of the proboscis alone.[1]

Vegetable-feeding insects have little or no difficulty in procuring food. All nature lies before them, and unerring instinct is a guide that never fails or falters in directing them, by flight or foot, to the substance constituting their proper aliment. It is only under extraordinary circumstances, in face of the unwonted destruction of plants or when the numbers of these tribes are unusually increased, that they ever perish from starvation. The carnivorous species experience a harder struggle for existence. They are exposed to the dangers of deficiency and deprivation, but fortunately they are frequently endowed with the faculty of enduring long abstinence. The kind of food they take leads them to employ a variety of methods in supplying their wants. A large proportion attack their prey by open violence, which is a clumsy and unsportsmanlike mode at best. Or they surprise insects by hiding behind a stick or stone, affording concealment until their approach. The predaceous hypocritical "praying Mantis"—so called because the posture that it assumes is supposed to resemble the attitude of a person at prayer—feigns sleep or death. But a few species have acquired far higher art in providing their sustenance. They have recourse to artifice and stratagem. This is in itself a fact of great singularity,

[1] Newport.

and the instruments by which these carnivora take their prey are admirably adapted to the end in view.

The Ant-Lion (*Myrmeleo formicaleo*) may be adduced as an interesting example. It is endowed with little talent as far as its powers of body are concerned, but that which it has it turns to good account. As a larva it is wholly carnivorous, and shows preference for smart able-bodied insects. Besides it is an epicure, spurning all food, however great its hunger, unless it be fresh caught and killed, so to speak, by its own hand. To look at it one would laugh at its pretensions to sport. In form it is short, flat, squat, and excessively clumsy, its body is soft and fleshy, its motion is sluggish, its legs are slender and feeble, its pace is absurdly slow; moreover, it can merely walk backwards. What luck could this creature have in the chase? Neither could it succeed in obtaining food by lying in wait for its prey exposed, since its jaws are so ferocious in appearance as to incline every insect to give it respectful berth. Its object is to conceal itself, to do which it adopts a well-laid plan, for though it appears inert and helpless it is no bungled performance of nature as some foolish persons would have us to believe. On the contrary, its structure is exactly what is required to render it competent to capture living and active delicacies.

Choosing a fine light sandy soil, little exposed

except to the sun, and generally in the neighbourhood of trees where ants are likely to have set up house, the Ant-Lion vigorously proceeds to construct its snare. It begins by pushing itself backwards in a circular direction so as to trace a shallow furrow varying from one to three inches in diameter. A succession of these furrows is formed one within the other, each being of course smaller than the previous one, and the larva with its broad shovel-like head scoops up and throws out the sand beyond the limits of its precincts. By this means a conical or funnel-shaped pit is at last completed, of no great depth but with very loose sides. The insect's labour being over, it ensconces itself at the bottom of the trap in the sand, leaving its enormous jaws alone exposed and widely extended. Here it sits in crafty motionless vigilance, in wait for what may come.

Ants, like monkeys and children, are distinguished for an insatiable curiosity, and should one spy the cavity when it is abroad on the out-look for food it would never hesitate to approach the edge. Its satisfaction seals its doom. It gets a glimpse of the ogre, and in vain it endeavours to retreat, for the treacherous sand gives way beneath its weight, and the hapless thing goes rolling down into the greedy outstretched jaws of the fortress's Giant Grimm, and a sharp bite soon puts an end to its existence. In a short time it is sucked dry, and the dead and withered carcase is flung from

lease they send down the sand in torrents, which fills up the pit, rendering its sides far less steep and therefore easier to surmount, for a powerful insect is better able to withstand such an avalanche than a tiny ant. Then ensues a battle royal, the one opponent fast bringing down the sand which the other as determinedly ejects, being bent on keeping itself free and on restoring its house to its pristine neatness. Sometimes a load flung by the Ant-Lion strikes the retreating creature unawares, and it loses its balance never to regain it, giving the larva just the opportunity that it needed to grasp it in its terrible sickle-shaped mandibles. Sometimes the captive becomes exhausted before the Ant-Lion and allows itself to be caught; and sometimes, though rarely, the onslaught ends in victory on the former's part, and it succeeds in making good its escape. In any case the pit has suffered such damage that its owner does not spend time on rearranging and repairing it, but abandons it, and starts on a fresh series of excavating operations.

In this manner, burrowing in the earth and catching living prey, the larva lives until it is full-grown and fed. The early immature period lasts for about two years. It then retires under the sand, and spins a cocoon of silk mingled with sand, and after the lapse of a few weeks is transformed into the winged and perfect state. The adults are not in the least like the larvæ. It would be hard

the pit, with an odd jerk of the Ant-Lion's head, in order to leave the trap unencumbered and ready for future conquest.

The victim does not tamely resign its life to its captor without attempting to save itself. A plucky ant is incapable of cowardly conduct of the sort. But it will be readily perceived that the more frantic are its endeavours to elude its fate by scrambling, the greater is the displacement of the yielding sand, its movements become more and more impeded, it is overpowered, and slowly but surely driven within reach of the murderous jaws. That the Ant-Lion intentionally aids in bringing about the result by dashing showers of sand at the struggling insect is probably somewhat of an exaggeration, for one can hardly credit it with flinging the pellets with any definite aim. The captive in its struggles must cause a quantity of sand to fall into the pit, and the larva feeling its house tumbling in, instinctively tosses it out. Some of this may hit the ant, and in that case will certainly bring it nearer the jaws.

Naturally should a large and unwary hunting-spider, a wood-louse, or perhaps a beetle, pay the penalty of inquisitiveness and fall down the hole, the fight between the snarer and its prey waxes fiercer and more prolonged. These prisoners have no idea of surrendering at discretion. They are sore at their own folly, indignant at being betrayed, and in their furious exertions to find re-

to conceive a more complete contrast, and were the two forms placed side by side no one unacquainted with the circumstance would believe them to be but two stages of the same insect. The perfect Ant-Lion is very elegant and handsome, of a dark grey colour with yellow spots. Its large transparent wings, four in number, are ornamented with black marks. In appearance, in fact, it bears many points of resemblance to the dragon-fly.

CHAPTER III

HERMIT HOMES

Methods of formation of homes constitute remarkable phase of habits and economy of insects — A home necessary by reason of nature of life of insects — Habitations of solitary insects for their young — Solitary bees — Solitary wasps — Galls — Habitations of solitary larvæ for own use — Homes of solitary architects being perfect insects for own use and also for that of their young — Trap-door and other spiders.

Of all the phases of the habits and economy of the insect world, none present more remarkable peculiarities, and are calculated to arouse deeper feelings of interest and appreciation, than the methods that these little beings employ to provide themselves with homes. We regard with admiration the architecture of the nests of various birds, we yield the palm to the villages of the beaver among the structures of quadrupeds, but for the acme of indefatigable industry, perseverance, and ingenuity, we must look to the habitations of the tiny insects. The very nature of an insect's life renders a home more absolutely necessary to it than to almost any other creature. During all its immaturity, to leave its perfect stage entirely out of the question, it would obviously be particularly open to dangers of weather and natural enemies.

But here the most powerful of its instincts steps in to its aid, the instinct that has for its object preservation of the species. Gifted with what seems almost miraculous foresight, many insects, at the expense of incalculable labour, prepare a home, comprising not only an abode but a storehouse of food, where their offspring, which they may or may not be destined to see, and whose habits are entirely unlike the parents', may in safety, as complete as possible, pass through the whole series of infantile helplessness, and emerge from it to take their place in and cope with the world, only when they have attained to the perfect form. This instinct is in other cases exercised by insects for their own accommodation, for their larval, pupal, or imago conditions; the habitations being merely

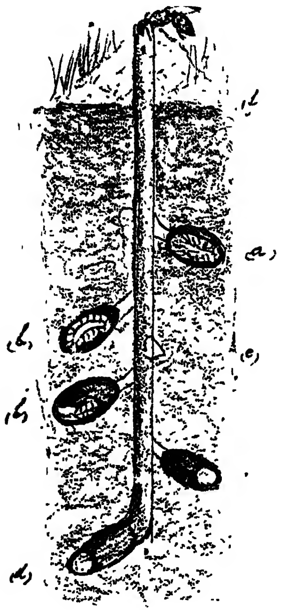

FIG. 5.—Profile view of nest of a Mining Bee (*Andrena vicina*, Smith), which builds her nest in grassy fields. (*a*) Oldest cell containing pupa; (*b b*) cells containing larvæ; (*c*) cell containing pollen-mass, and egg; (*d*) the most recent cell containing a freshly deposited pollen-mass; (*e*) the beginning of a cell; (*f*) the level of the ground; from Packard.

refuges or shelters, or affording board in addition to lodgment. For these purposes some burrow subterranean galleries in the ground, some excavate different parts of vegetation, some build houses of mud, clay, or sand; some of leaves, bits of stick, grass and shells; some roll up leaves with artful care, and dwell therein; some construct homes of excretions from their own bodies. In fact, the variety of these admirable contrivances is nearly infinite; and many for proportionate size and solidity, in complexity of arrangement, and the complete manner that they subserve the intention of formation, may very well be compared with the structures of reasoning man himself.

In this chapter it is proposed to deal with the habitations of insects living in a state of solitude, and built each by a single individual, leaving the social communities which unite in the labours of construction to be dealt with later on. The latter class are better known, perhaps, because they are more striking on a general view; but intimate acquaintance with both leaves it a difficult matter to decide which kind exceeds the other in wonder and attractiveness.

We are all acquainted with the proverbial busyness, the arrangements and policy of the ordinary hive bee, for the care and rearing of its young. With like object, and carried out with incomparable art and activity, are the homes of many of its wild

and solitary relatives. Among these bees there is no special laborious worker,* and since the male is an equally idle member of society as the drone of the hive, the duty of providing for the wants of the future brood devolves solely on the mother. Awakening from her winter sleep, she loses no time in fulfilling her mission. She has to select the site of the house that is to be, and to fashion it; to discover and collect nourishment, and stock it in her cells, in quantity sufficient for the proper development of the larvæ, no less and no more, but just enough. She lays her eggs, and shortly after dies. If any fighting with enemies has to be done while her operations are in progress, she it is who does it, so her position in life is no enviable sinecure.

A group of these bees is popularly called the *Miners*, a name fancifully bestowed upon them by Reaumur to indicate the character of their labours. They are little creatures (*Andrena*), but in spite of diminutive proportions they are admirable burrowers, driving their tunnels into the ground or masonry to a depth of eight or ten inches. The soil they select is often hard, such that an ordinary pocket-knife makes no impression upon it, as a well-trodden pathway baked by the sun; occasionally they choose loose sand. Usually the burrow is dug in a perpendicular direction for several inches, when it takes a sudden turn, and forms a rounded chamber. Here the bee deposits a store

of pollen * mixed with honey, and lays a single egg. Creeping outside she closes the orifice securely with the material she has expelled in excavation, leaving the egg to hatch and the young to come to maturity and escape in due season. Some members of this genus, and of Halictus, save themselves the trouble of making a number of separate burrows. They add short supplementary chambers, not more than an inch or so long, from the sides of the first and main shaft, and opening into it. In each is placed an egg and its food. All the inmates, therefore, though they lie secluded one from the other, emerge from their nursery, when their time comes, by a common entrance (see Fig. 5).

The *Carpenters* are solitary bees so called from the circumstance of their working in wood; technically they are termed *Xylocopa*, a word that literally means a "wood-cutter." As far as we are aware, none of the genus are indigenous to this country, but they are scattered over all the warmer regions of the world. A trunk or branch of a tree answers their purpose, and they are particularly partial to old posts, or wood railings, and to the wood-work of houses which has become soft, because beginning to decay. They are never averse to adopting any ready-made hole that they may come across, provided it is not too large; they even refurbish up old nests deserted since a former season's occupation. *Xylocopa violacea* may be

taken as typical * of the race, a lovely creature, larger than the largest humble-bee, with brilliant blue-violet coloured wings and a black velvety body, a native of Southern Europe. The female appears in the early spring, and at once seeks a spot to commence her arduous undertaking. Its selection is evidently a matter of moment and considerable time is spent in repeated and thorough investigation ere she fixes upon the wood. An upright piece is usually decided upon, and with her powerful jaws she begins a severe process of boring. For about the depth of an inch she works obliquely downwards, suddenly the course is altered, and she proceeds perpendicularly and parallel to the sides of the wood, until a tunnel is sunk, of a length no less than twelve or fifteen inches, and perhaps half an inch wide. As though this remarkable exploit were not enough, where the diameter will admit of it, sometimes three or four of these cylindrical tunnels are excavated side by side, a task which takes several weeks of incessant labour.

One would judge the nest to be now complete and ready for the progeny; but no, much more remains to be accomplished. It is necessary for the proper development of the offspring that each should have a separate apartment, and be supplied with its appropriate quantity of food. Having finished the bore to perfection — it is made absolutely clean, and smooth, and regular, as though

chiselled by a joiner—and having deposited a single egg at the bottom along with a ball of pollen and honey, the bee covers this over with a ceiling at the height of nearly an inch up the tube. Where, you may ask, does she obtain her material,

FIG. 6.—Nest of an Australian Carpenter Bee (*Lestis bombylans*).

and how is this partition constructed? During her excavation, the quantities of fibres detached were carefully stowed away in a neat little heap at a short distance from the nest, and sheltered from the action of the wind. Here then is the

wherewithal that she stands in need of. With particles of this sawdust, cemented together with her own natural glue and to the sides of the tunnel, she lays the foundation of the partition in the form of a narrow annular ring. Being hardened, it affords support for another ring along its interior edge; thus the orifice is gradually contracted, and is closed with a circular plate. Though the mass is made up of these fragments, it is almost flat and solid, and exhibits the appearance of as many concentric circles as there have been pauses in the work. It looks not unlike the annual zones in a cross-section of a tree, or a slice cut through the middle of an onion. This, the ceiling of the first cell, serves as the floor of the second. In the latter apartment another egg is lodged and is furnished with nourishment, and receives a ceiling. In this manner the bee continues until the hole is divided into ten or twelve chambers, each with its egg and pollen (see Fig. 6), when she closes the entrance, shutting all well in lest the contents should fall victim to some unscrupulous enemy.

Obviously a considerable interval of time must supervene between the laying of the first and the last egg, while the bee is engaged in the herculean labour of building up the various successive cell-partitions — ring upon ring, particle by particle — and in provisioning the occupants of the intervening cells, involving long toil and diligent

search. Naturally the lowermost egg must turn into grub, and pupa, and perfect insect, long before that finally deposited. What then becomes of it? Its mandibles are not strong enough to pierce a passage out through the wood. It is impossible that it can gnaw its way through the eleven superincumbent cells to the original entrance without damaging their immature inmates; and equally impossible that it can remain imprisoned till they one and all have effected their escape. The mother provides against this contingency. She constructs not only one point of access to her dwelling, at the farther end she likewise makes a lateral horizontal opening, a kind of back-door, and chokes it with sawdust paste, which being soft will readily yield to the tender jaws of her offspring. Through this door the first-born emerges into day, as in fact does each insect, one after the other in succession in priority of development; for by an exquisite arrangement, every grub when about to turn to pupa places itself in its cell head downwards, and thus in a position eventually to break open the cell in that direction.

The *Mason* bees of Reaumur belonging to the genera *Osmia* and *Chalicodoma* are remarkable for the singular variety of their architecture, or it would be nearer the truth to say that they are gifted with remarkable power of adaptation to circumstances, and vary the details of their operations, through all of which runs one undeviating

plan. Their structures are elaborate, and they exercise peculiar care as to the materials used, each species selecting a particular substance; the site of the home is also subject to much fluctuation. Differing from all others — this applies especially to the Osmia — in having their hind legs unsuited for the gathering of pollen, they achieve the collection of food by a multitude of stiffish hairs on the rings of the lower part of the abdomen. One of the commonest mason bees, the large and massive *Chalicodoma muraria*, or in plain English the "stone house," a name derived from its building capabilities, is a builder in the ordinary sense of the word, for its homes are not of the more primitive burrow type, but are erections and of true masonry. On a rock, or stone, or wall of sunny aspect, they may constantly be seen, irregular, oblong, or egg-shaped masses, looking to the casual observer like so many splashes of mud which had been thrown against the wall and had become hardened. Suppose the bee to have chosen the site of her future dwelling, as with all others a matter for deliberation. Off she flies to a spot where suitable building-stuffs are obtainable, and with her mandibles collects sand and small stones, and glues them with her viscid saliva to a few grains of earth, adding little quantity to little quantity until a pellet is cemented, the size of small shot. The ball of mortar being formed, is borne off in her jaws and fixed on the place

determined. When she deems sufficient material laid she mixes all the earth, and completes a cell about an inch long and half an inch broad. She enters and anxiously smooths it, she stocks it with a cake of pollen and honey, and lays an egg in the midst, then it is walled over. Other cells are

Fig. 7.—Clay nest of a Solitary Wasp (*Eumenes*) in early stage; from Natal.

similarly erected close by, up to the number of twelve or more. Their order of deposition is not regular; they may be parallel to the foundation, perpendicular to it, or at every conceivable angle of inclination. The building is not yet finished, for the group receives a sort of roof or general covering, composed of coarser grains of sand than those hitherto entering into the composition. One

more provision must be made for the well-being of the precious sojourners. A crevice that was left open from each cell to the exterior surface when the final wall was added is now stopped up with rather soft sand, easily penetrated by the feeble jaws of the young.

These bees appear to keep a sharp look-out for the ruins of any last year's nests that afford possibility of repair, and re-making as good as new. Finding an old home they go vigorously to work upon it; the cells are swept clean of all *débris* that has accumulated — the skins of larvæ, cocoons, and what not — any holes and imperfections are attended to, and the chambers victualled and closed up. Laziness even brings the masons to dishonesty. They will unlawfully intrude into a house in course of erection, the possession of another, and fight desperately to retain the prize. Some Osmiæ adopt the simple and less onerous plan as compared with the labours of Chalicodoma of placing their cells in decaying wood, or in the stems of the blackberry, the rose, and other shrubs, or within straws, as the industrious and tiny Chelostomes. One species merely attaches a number of balls of pollen, each with an egg, to the under surface of some flat stone. The larvæ when full-fed spin their cocoons on the spots which the pollen balls previously occupied. *Osmia bicolor*, a species indigenous to Southern Europe and found in England, utilises abandoned shells of garden

snails as ready-made burrows. Strangely enough, ~~the last~~ laid eggs, in the cells at the mouth of the shell, produce males, which are developed before the female insects, who inhabit the end of the whorl. The females therefore pass out through the deserted male premises above them.

The Megachile are celebrated for the beauty and singularity of their nests. This is the most cosmopolitan of all the genera of bees; numerous alike in the tropics and the colder latitudes, extending as far northwards as Hudson's Bay. Their peculiarity, whence is derived their generic title, literally signifying "large-muzzled," lies in their long and powerful mandibles, and with these instruments the species dubbed the "Leaf-cutters" perform the clever feat that their name implies. Under the popular term are included the British and all the known European specimens. These agree in the habit of making curious burrows for their young, in the earth or in wood, lined with cuttings of leaves, or the petals of flowers, abstracted from plants with wonderful precision and accuracy.

M. centuncularis, a little bee, is endowed with striking intelligence, though it is by no means remarkable to look at, like many another clever creature, for Nature, it would seem, is ever loth to cumulate her choicest gifts, and generally balances any lavish supply of blessing, physical or mental, by corresponding deprivation of the quality

opposed to that bestowed. The bee usually begins, but she is capricious in choice of site, by excavating a cylindrical tunnel in tolerably solid earth. It is bored in a perpendicular direction for a few inches, and afterwards enlarged into a horizontal chamber of good size. Within the latter, starting at the bottom and progressing upwards, eight to ten cells are constructed, composed entirely of portions of leaf, like a file of thimbles, the small and convex end of each fitting well into the large and open mouth of the cell previous. Ten or twelve pieces of leaf of different shapes are cut and carried to the bottom of the gallery, and there twisted and folded one within the other, so as to form a pretty funnel-shaped cone from a quarter to a third of an inch long, narrower at the closed extremity than at the orifice. The pieces are always placed so that no two joinings come together, the middle of one scrap lies over the margins of two bits immediately below, strengthening the whole fabric. Making up a ball of pollen and honey the bee places it inside, and with it an egg. Once more recourse is had to the rose, and a fragment of leaf is taken off so exactly circular that a pair of compasses would not do it more nicely, and of a diameter fitting precisely the cell's mouth. Into this the morsel is thrust with its convexity turned downwards; a second piece, a third, sometimes a fourth, are added, to obviate the faintest possibility of oozing of the honey.

The slightly concave surface of this lid receives the following cell which is completed in like manner, and gradually the series is built up. All being finished, endeavour is made to hide the entrance to the shaft with the earth expelled to form it, and to such good purpose that no trace is left of this marvellous work.

The bee, to obtain her building material, rests firmly on the edge of a leaf, usually so that it passes between her legs. With her strong mandibles she quickly cuts out the roundish portion she requires, as with a pair of scissors, turning upon a pivot with her feet; and lest its weight should carry her to the ground, just before the last fibre is severed she balances herself in the air for flight, and at the moment it parts bears it off in her jaws in triumph.

Anthocopa papaveris, the "abeille tapissière" of Reaumur, as though fascinated by the brilliant colour, fixes its choice of cell-lining upon the common scarlet poppy. It is small, of a velvety black, ornamented with white downy hairs on the margins of the segments of the abdomen. Its burrows are perpendicular holes in dry and sandy soils, perfectly cylindrical at first, but swelled out below in the shape of a Florence flask. The sides the bee stamps firm and smooth; then portion after portion, to the number of three or four layers, is cut from the poppy, each morsel as it is introduced into the cell being pressed and straightened

against the walls, to take out every curl and wrinkle from the delicate tissue. The honeyed provision and the solitary egg being committed to this cosy apartment, the upholsterer carefully folds in the free ends of the petals, a necessary precaution owing to the nature of the soil, to prevent the encroachment of the grains of sand. This done, the rest of the hole is stopped with earth.

Some of the exotic * species of Megachile, as *M. lanata* and *M. disjuncta*, common to India, form tubes of agglutinated particles of sand or clay independently of a burrow. They also fill up the hollows of tree-stems with clay cells, instead of a lining of leaves, built end to end in long lines, but with very little cohesion. The tenacity with which the clay adheres to the wood, however, is remarkable, and probably it is inspissated with some glutinous substance ejected by the insect.

Equal in interest to the nests of bees, and constructed with similar purpose, are the homes of many solitary wasps, and other so-called Fossorial * Hymenoptera. However well defined so far as external characteristics are concerned, the families have many mutual resemblances in their habits of life, though each species has its own particular fancies as to site of home, and food, and other details. Like bees, in the adult state they live on honey and such-like vegetable fluids, but the larvæ are flesh-feeders, and we see the curious

and suggestive sight of non-carnivorous mothers chasing and bringing down insect prey for their carnivorous offspring. One point in connection with this feeding deserves special mention — the young must derive their nourishment not merely from animal substances, but from actual living tissues. Inert, unarmed, unable to help themselves, or to move from the spot where they are hatched, how can they ever have living insects in their power? The difficulties to be paved away seem insurmountable. Nature holds a fairy wand; it is the mother who provides for them. In capturing insects she does not kill them, she inserts her venomous sting in her victims, producing a long, indeed a fatal, lethargy,* for the poison seems to preserve the unfortunate creatures from death and decay. In this condition she carries them to her cells, in this condition they lie, condemned to be slowly eaten by the hymenopterous larvæ. Let us hope kind Nature deprives the luckless beings of consciousness in the same moment that they are robbed of animation.

FIG. 8. — Pelopæus Wasp building nest; from Bates.

The Fossores belonging to the genus *Odynerus*, or the False Wasps, are pretty little black things, striped with yellow, noted for their agility and graceful movements. The Masons of Reaumur may constantly be seen in this country in great numbers, flying to and fro over a hard, sandy, or gravelly bank exposed to the sun, boring their tunnels and storing them often with the green larvæ of a weevil,* of which as many as fifteen or sixteen may be put in one cell. They raise a fanciful cylindrical tube over the mouth of their burrow; when finished, it often projects from the soil no less than two or three inches. It is formed of pellets of earth arranged in circles one over and in front of the others, with small intervening spaces left open between the masses, giving it the appearance of filigree work. For the greater part of its length it is upright, but towards the top is carried downwards to describe a slight curve. The use of this vestibule is doubtful; perhaps it may prevent the incursions of artful parasites, who may fear to enter so long a defile. Whatever the object may be, it is a temporary one. Present only while the victualling is going on, and the eggs are laid, subsequently this entrance to the gallery is pulled down, and constitutes the material that goes to fill up the lip of the hole.

Eumenes coarctata, the only British example of its genus, an odd-looking wasp, has the first segment of its abdomen drawn out to form a decided

foot-stalk, so that the abdomen appears joined to the thorax as by a bit of fine black wire. Its nests are small, globular, and vase-like, built of mud, and fastened to the stems of various plants, the common heath being the greatest favourite. Each contains one cell, and is the habitation of one occupant. *E. pomiformis* affixes her nests to walls. *E. petiolata*, *conica*, and *esuriens*, Indian species, seem to prefer the woodwork of houses, such as door- and window-frames and posts, and, where the locality is suitable, sometimes a succession of cells will be constructed side by side, often more than a foot in length. The nest of *petiolata* is the size of a pigeon's egg. Whatever the exigencies of the situation, the *Eumenes* strives to retain the spherical form of the edifice and the recurving brim (see Fig. 7).

The Sphegidæ, Pompilidæ, and Bembecidæ, are popularly classed together as the Sand-wasps. As their name denotes, they love to form homes in sandy earth, where they lay eggs, and stock them with living insects, rendered powerless by their poisonous stings. The well-known Sphex, the typical genus of the Sphegidæ, is scattered over the greater part of the world; the English species —there is but one—is somewhat common in the eastern counties. Ammophila afford an excellent instance of the ordinary manner in which these insects prepare their burrow. It consists of a long, narrow gallery, opening into an enlarged

chamber, a formation calculated to enable the mother, after storing the prey she has secured, to regain the surface. She descends into the tunnel backwards, dragging her burden after her, and were it the same size in every part, there would be no room for her to creep from under the food, and to pass out. The genus Pelopæus are inhabitants principally of warm climates. Many are excellent masons, and may be watched at muddy puddles, kneading and rolling up clay into spherical pellets, and carrying them off in their mandibles to form the future residences (see Fig. 8). The oddest spots imaginable are often chosen for their sites. Sometimes a cell is separately constructed; sometimes one is placed over another; but generally the nest is composed of a number of cells, built side by side upon the same horizontal line, each being filled with food and closed as completed. The whole is covered exteriorly with a smooth coating of mud. The mothers are bold and fearless hunters, and think little of attacking strong and well-armed spiders. Doubtless their sting is a terrible weapon, and when once the enemy is struck, taken unawares it may be, all is over. But the spider, if on the outlook, sometimes manages to cast its web-threads over the Pelopæus, and paralyses its movements ere the fatal arrow is shot. Soft plump spiders, one would naturally think, would be chosen by the wasps. But in tropical America *P. fistularis* culls those belonging

to a large group allied to our common garden spider, all possessed of hard shelly polished coverings, not even smooth, but shooting out into the most fantastic and formidable projections. The genus Pompilus rival the Sphegidæ in bravery and cunning in catching prey. They also provide spiders for their larvæ, mostly wandering kinds which never make webs. In this country, where about twenty species of Pompilus are known, they are of small size and unimposing.

In another class of habitation for the young the homes serve in the dual capacity for the shelter and the sustenance of the occupants, and though they spring from the mother's work they rise independently of her construction. It will be understood that we speak of galls, vegetable excrescences that we all know well. They differ in appearance, shapes, and sizes, and affect multitudes of plants, though the oak is especially prone to the attack. All parts of the plant are infested by them, the leaves, the buds, the trunk, the twigs, even the flowers, the fruit, and the root. Every one has observed these abnormal growths, but comparatively few persons are acquainted with the insects to which they owe their origin, and with their young, for whose early up-bringing alone they exist.

The Hymenoptera that produce galls constitute a group by themselves, the Cynipidæ, which contains the genus Cynips, and others very much like

it. Though they vary greatly, a striking family resemblance runs through them all. They have

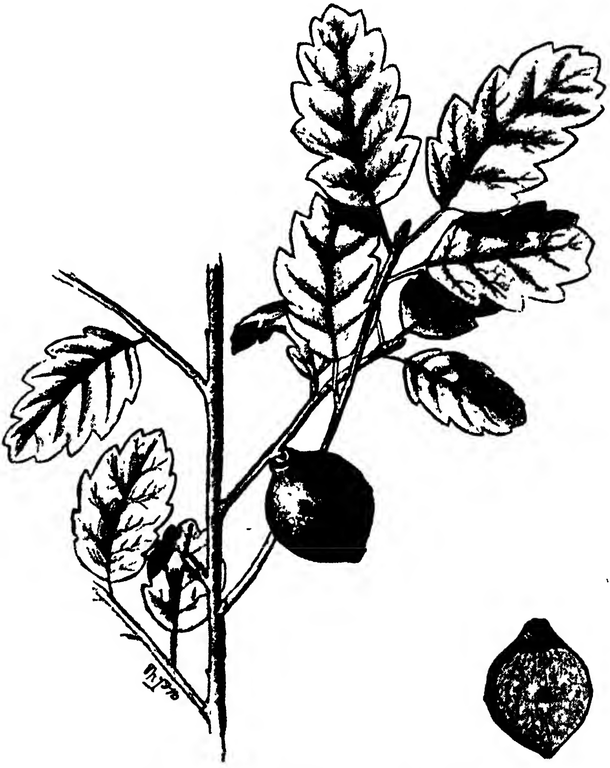

FIG. 9.—Galls of *Cynips insana*, or Dead Sea Apples.

an oblong and very convex body, and the female is provided with a peculiar apparatus for egg-laying, the ovipositor, a slender hair-like tube,

which when not in action is coiled up, spiral fashion, within the abdomen. During spring and summer, when vegetation is in full sap, is the time for depositing the eggs. Having selected a proper spot, the "fly" straightens her ovipositor and thrusts it instantaneously into the leaf or other object, making a puncture, subsequently widened by boring. Into the hole she drops one or more eggs. To conclude, she spreads a slight quantity of secretion over the wound, so irritating to the plant's tissues as to alter their nature, and develop, but how we know not, the irregular swelling of the cellular structures that we term a gall. Midst the fleshy chamber thus constructed the eggs are hatched, and the larvæ live on its interior. The insects remain within the galls until they have undergone all their changes, and emerge, eating their way out into the open air, upon their attainment to the perfect form. Others escape as larvæ, and burrow into the earth for their later metamorphoses.

Forty-two or more kinds of galls occur on oaks in Great Britain alone, but the damage done to the trees seems almost immaterial. There are the familiar oak-apples, arranged usually several together in small clusters on the twigs and branches, irregular in shape, and sometimes of enormous size, the work of *Cynips terminalis*. These contain an aggregation of cellules, twelve to fifteen or more, the hermit habitations of solitary larvæ,

From the separate cells a fibre, as it were, runs towards the base of the gall. Probably these fibres are the nervures of leaves which would have sprung from the bud in which the eggs were laid, had not the irritating fluid caused them to develop in a new manner. The well-known small oak-apples found in profusion on oak leaves are due to the puncture of *Cynips quercus folii*. Well they deserve their popular title of cherry-galls, being beautifully coloured, some scarlet, some white, some red and orange, in various gradations. Their surface is smooth and brightly shining; in substance they are of a soft pulpy consistency, not unlike a gooseberry or hot-house grape. In the centre of the mass is a solitary globular chamber containing a single larva snugly curled up. The undersides of oak leaves are also infested by small, flat, round, disc-like bodies, the common spangle galls of the *Neuroterus lenticularis*. They sometimes occur in such quantities, but rarely, as to weigh the leaves and cause premature withering. The elegant so-called currant galls that depend on slender threads from the oak's catkins resemble sparse bunches of currants. Their colour is another reason for their name, for they are sometimes scarlet and sometimes white.

The Rose Bedeguar, or Robin Redbreast's Pincushion, frequent on hedge-roses and sweet-briars, is formed by *C. rosæ*, an insect about the fifth of an inch long. She deposits her eggs towards the

end of May or beginning of June, with the result of great swelling of the stem, while the leaves are produced in ordinary numbers but without cellular * tissue between the fibro-vascular * bundles, causing the exterior of the fungus-like growth to be covered with numberless many-branched, hair-like filaments, the so-called "moss." These galls attain their full size on the approach of cold weather. How pretty they look at the close of summer tinted with green and red. When winter ultimately sets in, they lose all brilliancy and become uniformly brown. Although the soft compressible moss-like surface appears to form the whole of the gall, in reality there is a dense woody tissue, within which lie the larvæ admirably protected against injury from without. The number of cells in a Bedeguar is mostly great. They are usually restricted in size; larger dimensions seem always obtained at the expense of solidity of the walls. Each cell contains a single egg, and each in its own restricted space the larvæ are hatched. In this stage they remain quietly at rest for the winter, quickly changing to pupæ and the perfect forms at the beginning of the following spring. Should the spring be cold the "flies" do not at once desert their home on the completion of their metamorphoses, but await the arrival of propitious weather. Then they gnaw their way through their abode and escape.

The gall nuts of commerce, or Aleppo galls,

used to make ink and tinctures and whence gallic * acid is derived, affect the leaves and twigs of an Eastern species of oak (*Quercus infectoria* *), abundant in Asia Minor and Turkey. They are remarkably hard, and almost spherical and tuberculated.* Their juice may be said to be colourless, but if it is mixed with a solution of the sulphate of iron or copperas, itself very pale green, the two combined produce a fluid intensely black, such as the ink in common use. Any one may prove the fact for himself, and manufacture ink on a small scale, by cutting some succulent British gall with a steel knife, and he will find his fingers stained as with pale ink by the action of the iron on the moisture of the gall.

The so-called Dead Sea fruits, apples of Sodom, or *Mala insana* (see Fig. 9), grow on dwarf members of the same oak on the borders of the Dead Sea. About them strange stories have been told, and their nature once aroused controversy amongst commentators upon Biblical and Oriental literature. Travellers used to describe these

> Dead Sea fruits that tempt the eye,
> But turn to ashes on the lips;

beautiful to look upon with their glossy deeply-purplish red surface, and as large as good-sized apples. But when tasted, instead of the sweet juicy substance one was led to expect by the lovely exterior, they filled the mouth with bitter dry ashes, drawn,

so it was said, by the oak from the ruins of three evil cities buried beneath the bituminous waves of the Dead Sea. Hence the "fruits" were tangible evidence of the cities' former existence. For many a day this story was believed; at length it was dismissed, the very existence of the "fruits" was denied as the invention of an Eastern fable, in spite of plain allusions to the contrary by Josephus, Strabo, Tacitus, and other ancient authors. Recent research proves the main facts of the case to be correct; the inferences deduced fare badly. These "fruits" are galls of a Cynips named by Westwood *insana*. They do not belie the old descriptions of their beauty, and naturally they are astringent, more especially as they grow upon an oak. Doubtless they will prove sufficiently so, if any one care to make the test, as to warrant the tales of the rough and ash-like sensation they produced on the palate in the days gone by.

Cynipidæ are not the only insects that originate galls. In the beetle group some of the weevils pass their early stages in swellings brought about by the parents. The Cecidomyia in the order Diptera, the saw-flies, the aphides, the moths, and many more are likewise gall-makers.

No form of habitation can be simpler and more natural than the burrow, and when it is made in seeking for, or in eating, food, the point seems to be reached at which simplicity of design can go

no farther. Many an insect that to see is to admire — fragile, beautiful in brilliant colour, soaring in the air, exulting in the sunbeams — indebted to its own exertions, has passed the previous portion of its life thus hidden in the interior of a tree trunk, a branch, a leaf, or a root, even in fruit or in the earth, feeding greedily on its surroundings or upon any prey that might come within its reach. In these concealed situations it has entered upon its etherealised winged state, and become equipped for its higher position and purer atmosphere.

Of this nature are the homes of the larvæ of one of the wasp-like moths, *Sesia apiformis*. These caterpillars are pale in colour, and at a glance one judges them to be wood-eaters. The eggs are laid on the bark of poplar trees, and when hatched the young at once make their way into the interior of the trunks, and eat out tunnels of considerable size for no less a period than two years previous to their metamorphosis into chrysalides. For this labour the grubs are admirably adapted, while they are quite unsuited for browsing upon tender succulent* leaves. Their forcible jaws readily rend the dense woody tissue; the legs are small, so as to prove no hindrance in the narrow tunnels; and the head is protected by a hard and reddish integument, affording solid support for the strong masticating apparatus. Larvæ of moths of the family Hepialidæ, abundant in Africa, America,

and Australia, many of them of enormous size, have exactly similar habits. Our own country is not exempt from the ravages of the wood-borers of Lepidoptera. One of the most injurious to many of our timber and fruit trees is the goat-moth

FIG. 10. — A Sack-bearing Caterpillar (*Saccophora*); from Bates.

caterpillar (*Cossus ligniperda*), so-called from an oily fluid that it exudes from its mouth of a very rank and pungent goat-like odour. The caterpillars are hatched in crevices in the bark, and at first they feed in the bark, or between that and the wood. As soon as size and strength permit, they

penetrate into the living tree, and make galleries and chambers, larger perhaps than those of any of our wood-boring enemies. Proportionately as the

FIG. 11.—*Metura Sandersii* from Australia; (a female.)

larva increases — and its growth is amazing — the diameter of its burrow becomes enlarged; and since its course is erratic, and it remains in the larval condition for fully three years, the mischief it perpetrates is great. During the winter, however, it lies dormant, and does not feed, in a cocoon ingeniously constructed from wood-chips roughly spun together with silk thread. This nest is often over two inches long and one in width.

The larvæ of the Scarabæidæ, the giants of their order (Coleoptera), are likewise notable wood-borers. Fortunately for us, for the amount of vegetable matter that they consume must be enormous, the larger species live exclusively in countries where a luxuriant vegetation can best afford their depredations. At home perhaps no wood-boring beetle is better known than the little *Scolytus destructor*. It is destructive, particularly to elms, both in its mature and larva states, and many large trees, and even whole forests, succumb to its attacks. The mother enters the tree in search of food; and to lay her eggs she squeezes herself in between the bark and the wood, where she bores out a cylindrical gallery, usually from three to five inches long, taking her about three weeks to complete. Along the sides the eggs are laid at regular distances apart, to the number occasionally of a hundred and upwards. She then generally retreats to the entrance and dies. As soon as the larvæ

are born they begin to feed. Urged by a wonderful instinct each arranges its body at right angles with the parent gallery, and proceeds to gnaw the wood steadily outwards. These side alleys become gradually larger to allow room for the growing tenants, but they all radiate from the central tunnel, and rarely interfere with each other by coalescence, their radiation more than keeping pace with their increasing size. Had the grubs all started parallel with each other the tunnels must have joined, and confusion and deprivation of sufficient food would have been the consequence. Full-fed, the larvæ turn to pupæ, and eventually pierce the bark and emerge. Large species of Calandra larvæ, some two inches long, commit fearful devastation in the tropics, boring into the pith of large trees and into sugar-cane. South America suffers similarly from the immense beetle *Titanus giganteus.* In the West Indies, while the grubs of *Lamia amputator* and an allied species excavate mimosa and acacia trees, the perfect insects complete the mischief of their young by gnawing round the branches in a circular line, all except the central pith. Sooner or later the stems fall to the ground by their own weight or by the force of the wind. The parents' action, it is presumed, is directed to the prevention of a large flow of sap into and through the branch, which might harm the enclosed larvæ and impede their metamorphoses.

The leaves of garden trees and plants, the rose

especially, are often traversed by white winding lines. Upon holding a leaf so marked to the light, the tracks are perceived to be due to the absence of the parenchyma; they are in fact galleries or tunnels between the upper and lower membranes burrowed out by larvæ, by the laborious procedure of eating the excavated material as they go. In most cases towards one end the gallery increases largely in width, and here the miner changes to pupa, and from this part flies when mature. The minuteness of these insects is realised when we consider that the thickness of many a leaf is not greater than that of this sheet of paper. Yet within this space the larvæ find room to exist. It is worth while to remember that the early states of winged insects are always large in proportion to the imago condition, much of the substance being taken up by the rudimentary wings. Leaf miners belong to the orders Lepidoptera, Coleoptera, and Diptera, though Lepidoptera furnishes by far the greatest numbers. These are so minute that they can hardly be recognised as moths, and are simply exquisite gems of Nature.

Amongst British Coleoptera, the common green tiger beetle (*Cicindela campestris*) is very interesting in its habits. Though small it is remarkable for fierceness, while for grace and beauty it challenges comparison with the grandest exotics. As a larva it has all the love for slaughter evinced by its parents, but its sedentary tastes and bodily

structure, its white delicate skin and short legs, would seem to preclude gratification of the desire. So far as chase or open assault is concerned it makes no attempt; it leaves warfare alone, and resorts to diplomacy. With its short stout and spiny legs and powerful jaws it burrows out a vertical tunnel in the ground, and its flattened head ejects the earth detached. The tunnel is a foot long and of a diameter adequate to admit of the larva passing up and down; towards the bottom it curves into a horizontal chamber. To make ready to catch its prey, the burrower ascends to the mouth of the opening, where it fixes itself steadily by pressing the back of its body against the walls, its eighth segment being developed into a hump-like projection which carries a pair of bent hooks. Its head and jaws lie perfectly level with the soil and are hardly visible, so that any insect will walk unsuspiciously over them. Instantly at the moment the larva feels the touch its sickle-like jaws are opened, it grasps the victim, and drags it to the bottom. Or the beetle upon becoming cognizant of the presence of the insect, slips with great precipitation down the burrow, and naturally the prey falls in after it and is soon eaten.

An enormous variety of caterpillars, chiefly those of moths of the families Tineina and Tortricina, make homes of leaves, which they twist up and roll and fold and unite together to form safe habitations and abundant supplies of food. The genus

Halias, which are very common to France, do infinite mischief to the vines. From the eggs, laid on the top of vine leaves in the middle of summer, the caterpillars are soon hatched, but they do not at once begin to feed, though surrounded by abundance and the weather is warm, they swing themselves by silken threads waiting to be tossed about by the wind. By-and-by the larva touches some prop or stem of the vine, when it penetrates into cracks in the wood, or beneath the bark, and hybernates until the late spring of the following year. Climbing up a stem, it now binds the young leaves and little bunches of grapes into a comfortable home, subsequently eating away the inside. Some caterpillars confine their exertions to a single leaf. They fold it longitudinally and fasten the edges with silk; or transversely, attaching the point to the middle nervure. Some roll it longitudinally, others transversely, or part of it, to make a hollow cylinder. So minute are many of these insects that they cannot accomplish the feat by main force. Suppose the leaf is to be wrapped transversely. Again and again a series of silken cables are attached to its point and upper edges, their other ends are fastened to the centre. Each cable in succession is pulled and tightened by the larva's feet and spinneret until the structure bends over, when it is securely held in position by fresh and shorter threads. In this manner the work is continued until the leaf is rolled into the tubular form

desired, and the mechanic enters its home and feeds on the soft substance in almost perfect safety. In some cases the provision it obtains is ample; but should the life in larval state be long it may be compelled to construct other rolls, the nourishment from the first roll being exhausted.

One species of leaf-mining caterpillars (Coleophora) as soon as they have tunnelled a cavity in the leaf, cut out the mined portion to form a case, sewing the two sides together with silk. While the anterior orifice is circular, the posterior end is often diamond-shaped. Some Tinea, more saving of labour, make the tubes at the very edge of the leaf which acts in place of a seam. The owner does not repair or enlarge an old abode of the kind, but having eaten the best part of it, the larva abandons it and builds anew.

Other species of Tineina make homes at our expense out of bits of wool, hair, silk, or fur, from our dress and household stuffs, which they delight to gnaw. The tube of *Tinea tapetzella* is almost cylindrical, and though rough exteriorly, is daintily lined with silk spun from the artificer's own mouth. When about to turn to pupa the larva closes one end of the house and suspends it bottom downwards. Before transformation it faces round inside the case, directing its head towards the end unattached. This larva forms only one home, which is altered from time to time as it becomes too small by additions of threads to either extrem-

ity. Should the width need enlargement, the occupant cleverly inserts new material into apertures made lengthways for the purpose. In colour the case always corresponds with that of the substance from which it is taken, and quite a motley appearance may be given it if stuffs of various hues are placed in the way of the little manufacturer.

These dwellings are surpassed by the building performances of larvæ of a genus of the family Psychidæ, common to America, Australia, and Europe (see Fig. 11). Of all the species, the House Builder (*Oiketicus Sandersii*) is perhaps the most remarkable. The cases are made up of pieces of slender twigs, laid parallel to each other to form hollow cylinders, with care and exactness, much like the rods in old Roman fasces carried by lictors before the consuls; hence the popular title of the makers is Lictor Moths. Fragments of wood and leaves, morsels of straw or grass or sprigs of moss, bound together by silk, are likewise employed. These homes the inmates carry about with them as snails do their shells, the head and thoracic segments alone protruding to permit them to grasp the leaves and twigs or whatever they are crawling over. The portion thrust forward is, however, hardly distinguishable, and it is very curious to see a tube moving along apparently of itself. As regards large Psychidæ in America, the cases depend far beyond their bodies; sometimes the total length is as great as from four to five inches. If the larva

desire repose, it can retract its head and primary segments, and retire inside completely. To render itself quite safe when it is clinging to a branch, it can press the mouth of the tube against the branch so firmly that it is closed effectively; if detached, the mouth can be drawn together by stout silken threads, arranged around its circumference. When about to become a pupa the insect withdraws within the nest, and closes it; shut in, it prepares for its pupal sleep. The females of *Oiketicus Sandersii*, and of an allied genus, are wanting in wings, almost in legs and antennæ in the perfect state, and environed in the tubes they pass the whole of their existence. None but an entomologist would take them for mature Lepidoptera.

Remarkable residences built under water by the larvæ of Caddis Flies (Trichoptera) are wonderfully like these homes of Psychidæ. They are composed of fine stems of rushes and other plants, of bits of stick, leaves of grasses, minute pieces of bark and wood, fresh or decayed, of grains of sand, or gravel or mud, of hay, and any such *débris* that may have fallen into the water. Small fresh-water shells, yet occupied by their living inhabitants, are even affixed by the caddis to its case by their flat exterior, and the material or materials are glued together with a waterproof cement. The tubes tend to assume the cylindrical shape, and the interiors are lined with silk. Sometimes short lengths of plant stems are placed longitudinally

side by side, with the utmost regularity, to form a perfect and shapely cylinder, perhaps four inches long. The morsels may be wound spiral fashion,

Fig. 12. — Part of the nest of a Trap-door Spider (*Nemesia eleanora*) with single tube.

or may be disposed into a many-sided structure, and so on in endless variety of arrangement. The larvæ are each provided with two hooks on the soft skin of the end of the abdomen, so as to anchor itself firmly to its house. When about to undergo metamorphoses they fix their dwelling to something, and block up the ends, not with a solid stopping, with a kind of open fence, which, while it prevents the intrusion of enemies, allows free percolation of the water in and out. The adults may be observed any evening in summer flying about the banks of streams and marshes. The female enters the water to lay her eggs, which previous to this event she keeps for a short time in a green bundle attached to her body, her object being probably to expose them to the warmth of the sun before immersion. Enveloped in a glutinous mass they adhere to an aquatic plant, or to a stone. Upon an insect being hatched it immediately forms its tube, for the protection of its soft delicate body and in view of its carnivorous disposition. When the transformations are almost complete, it eats its way through the end, and leaves its pupal skin by flight at the surface of the water. Larger kinds crawl up the stems of aquatic plants before abandoning the pupal envelope. A few caddis worms make immovable habitations, fixed to the spot whereon they were constructed. The grub is then compensated by larger range of movement; its abdominal claspers are of much greater length

proportionately, allowing it to extend itself to some distance from the entrance.

Some moths (Hydrocampidæ) are aquatic during their larval period. A common species in France fashion homes for themselves out of two pieces of leaf, sewn as it were together with a little silk, whence their heads and thoracic segments appear, as in the caddis.

Among the habitations constructed by solitary architects, being perfect insects, for their own accommodation, some of the simplest are those of the mole and field crickets. The odd-looking mole cricket (*Gryllotalpa vulgaris*) is one of the largest insects in England, stouter and stronger than any, and like its namesake it is fierce and irascible, and exceedingly voracious. In shape, and also in many of its habits, it is the very counterpart of the mole. Its appearance testifies to its mode of life. The body is almost cylindrical, the tibiæ * of the fore-legs are short, broad, and flat, and as it were fingered, the feet being small, and almost hidden by the broad palmated legs to prevent them being injured when the cricket is digging. Armed with its spade-like apparatus, it burrows out large excavations in the ground to a greater or less depth, vertical shafts with long horizontal galleries abutting. As a rule, it prefers loose and made soils, as in kitchen and nursery gardens and vineries. It cuts and eats through everything that comes in its way, so that its ramifications are a grievous source

of mischief among young plants and flowers; in fields they may be of certain use, the tunnels forming a kind of sub-soil drainage. Like the mole, it reserves a distinct chamber apart from its other galleries for its young. Formed at no great distance below the surface, this room is about three inches in diameter, and nearly one inch high, very neatly made, and its walls are carefully levelled and hardened to resist the action of the rain. Here the eggs are laid secure from all ordinary foes, and no doubt their hatching is effected by the sun's warmth, which will penetrate to the slight depth at which they lie. Secluded in its home, the insect passes its life in a state of absolute solitude, issuing forth at nightfall, when alone it disports itself on its wings. It never soars to any great height.

In character and habits *Acheta campestris* is very similar. At night it comes out and sits just within the entrance to its hole, chirping away at its monotonous song for hours together. Being wary and timid, it takes alarm at the least noise, and retreats inside with precipitation. But it is combative, and may be drawn out by inserting down the tunnel a stick or straw, which it clutches as in a vice. In France children fasten a fly, or ant, to the thread, or stick, that they poke down the nest, but this is quite a superfluous addition, for it is anger and not hunger that incites the cricket to grasp the intruding object. The largest known

species (*A. monstrosa*) are natives of India, and make burrows sometimes three feet deep.

No solitary insects surpass spiders in house-building. Many of their homes are not merely intended for the rearing of their young, but are homes in the true sense of the word, where they reside day after day, and to which apparently they become fondly attached. They consist chiefly of burrows in the ground. Even in England we may come across little specimens tunnelled out in some sandy soil, and lined with silky membranous tubes to prevent the earth from falling in. From the mouth a web is spread to catch the prey, while the hunter lies concealed at the bottom, waiting for the approach and capture of victims in the snare above. The finest simple spider tunnels belong to the Mygalides, a family of the tropics that comprise the gigantic creatures of their tribe. Several species of the genus Mygale have great hairy bodies, almost as large as sparrows, and an expanse of limb no less than half a foot and more. One very robust fellow, *Mygale blondii* by name, a great burrower, forms a broad slanting tunnel some two feet deep, and the sides are lined with a silken coating. This spider is nocturnal, and may be seen at sunset occasionally at the mouth of its den, keeping watch for passing delicacies, which being caught are destroyed at leisure in the safe retreat. Probably it seldom wanders far from home.

The greatest perfection of tubular nests, however, culminates with the so-called trap-door spiders. For beauty of workmanship, for ingenuity in arrangement, for marvellous cleverness in overcoming difficulty and avoiding danger, these arachnids* must be assigned a front place among Nature's handicraftsmen. They inhabit many warm countries, notably the West Indies, the United States of America, India, and Australia. The typical nest is a cylindrical tunnel in the ground, beautifully lined with silken web and protected by a valve or lid — "the door" — fitted accurately into the frame of the orifice at the surface, and like our doors possessed of a hinge, upon which it turns with the greatest freedom, allowing it to be opened and closed at pleasure. Some of the larger kinds of these nests, as in the West Indies, are a foot deep and about an inch in diameter, and are dug out by the strong jaws of the spiders often in a steep bank of bare clay. The silken lining tube may be removed from the burrow, and is then seen to be double; the outer covering being comparatively strong, harsh, and thick, and deeply stained of the colour of the earth, while the texture of the inner layers is very different, being nearly white and soft, and smooth, the smoothness, however, not precluding certain irregularities of surface, it resembles rough and unsized paper. The door is composed of the same substance, and is continuous with the tube for about a third of its

circumference—forming the hinge—or sufficiently to ensure that it does not fall carelessly to either

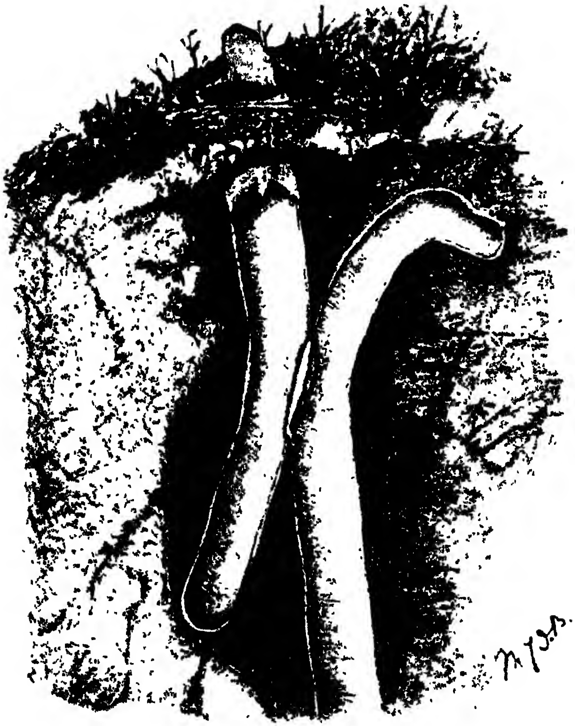

FIG. 18.—Part of the nest of *Nemesia meridionalis*, showing the surface-door open, and the lower door pushed across so as to close the principal tube. The subsidiary tube ends in a *cul-de-sac*.

side, but comes with precision into the mouth and closes it. Perfect closure is rendered a matter of

certainty by the aperture of the tube being slightly recurved to form a brim or lip, and the interior surface of the lid is a little convex. Exteriorly it is level with the ground, and the silk is coated with earthy particles. In fact, all trace of the work is completely obliterated. Travellers to the West Indies describe the alarm they at first experienced in seeing the earth open, a little lid lifted, and a formidable-looking spider peep out of the hole.

These tunnels are seldom situated in flat ground, where the door would lie horizontally when closed. A sloping or nearly vertical bank is usually chosen, and the hinge is placed at the highest side of the opening, so that the door when pushed up on the entrance or exit of the owner falls to by its own weight, ensuring concealment of the nest. The edges of the door are accurately adjusted to the bevelled lip of the tube, and offer a certain degree of mechanical resistance to the entry of an enemy. Should the spider be at home when his door is touched, he is made aware of the impending danger by the vibrations of the silken threads. Speeding to the scene of action, he hooks his hind legs to the lining of the lid, his fore-legs to the side of the tunnel, and turning upon his back resists the threatened invasion with all his might. Excessively bold and courageous, he defends his territory with the greatest pertinacity; nothing short of actual violence will induce him to desert it. In

some nests a row of minute holes, as though pricked with a fine needle, is pierced round the free edge of the lid, another row lies immediately within the margin of the tube. It has been suggested that these help the spider in holding the cover against attack; in Mr. Gosse's opinion they serve to admit light and air to the dwelling, and are indispensable, owing to the density of the lining material and the tightly-fitting lid. The row round the edge of the tube may be, as it were, a stock in reserve in case of accident, should the lid holes happen to become effaced with particles of the surrounding earth.

Some trap-door nests of the south of Europe (see Figs. 12 and 13) have thinner doors, less tough and coarse in texture, and frequently they are not wedged into the top of the tube like a stopper, they simply rest over it. Often the excavation is amidst moss and other low undergrowth, securing safety in obscurity of site. The lower extremity may end in a short spur-shaped enlargement. Sometimes a subsidiary branch is dug obliquely upwards from the middle to the surface, where it is lightly closed by a few silk threads; usually this shoot is a mere *cul-de-sac* (see Fig. 13). A hanging-door exists at the junction of the two tubes; and at the depth of two or three inches down the main one a door of the same kind may be found. If an enemy, a parasitic fly, for example, force its way into the nest by the principal, or the sole entrance, as the

case may be, the spider is believed to press up the last-mentioned door, leaving the intruder to all appearances to an empty domicile. Should this manœuvre fail, and the hunter be not deceived by the trick, the spider can dodge into the branch, and draw the second door to behind him. Where the branch extends to the surface, if needs be, he can evacuate his premises and escape.

Certain spiders (Lycosides) raise a cylindrical hollow tower over their burrow, much like an ordinary bird's nest on a diminutive scale, forming it very symmetrically of bits of grass, leaves, sticks, and rootlets, or of clay, little stones, and a few stronger sticks, loosely interwoven with silky secretion (see Fig. 14). Evidently it plays the same part as a trap-door, and contributes to the concealment of the hole. On removing it the shaft is found to be often twelve and fifteen inches long; in one instance a depth of twenty-two to twenty-three inches was reached. It is perfectly round and perpendicular, and may widen out into two enlarged chambers, an upper and a lower one, but the tunnels of many ground-spiders are of the same diameter throughout. Both the nest and the tube may be silk-lined, or the latter may be innocent of web; usually the entrance is neatly underwoven with this substance mixed with sand. Mrs. Treat, an eminent American naturalist, describes another species of spider as establishing a dome-like roof over its tunnel, made up of a canopy of

web overlaid with leaves, blades of grass, and such like matters, the whole being securely fastened down except at a place of entrance and exit, which is only discovered with the closest scrutiny. These spiders have the habit of closing this opening in the autumn season for the space of two or three weeks, in order to elude the raids of the fossorial wasps, who are then engaged in provisioning their young. The wasps run over the ground, peering into every nook and cranny, and should one alight upon a nest unbarricaded, down it goes and returns with the inmate, rendered powerless by its poisonous sting. During the winter the doors are likewise hermetically sealed.

FIG. 14.—Nest of the Turret Spider (*Lycosa arenicola*), United States, America.

Unlike most of its kind, the spider *Argyronetra aquatica* is aquatic, or rather amphibious, and habitually spends the greater portion of its time in the watery element, constructing its home, and surrounding itself with the atmospheric air essential for respiration. It may be found in various

parts of England — Cambridge is a favourite locality — in rivers and pools and ditches where the water is calm and untroubled. Its cell is composed of silk, and is more or less oval in shape and about half the size of a pigeon's egg, and is suspended in a vertical position, the open part being directed downwards. The spider commences by spinning loose threads of silk in different directions, attaching them to the leaves of water-plants — the framework of her building so to speak. Within these supports she sets her beautiful transparent chamber. Before occupation it is necessary that it be filled with air. Slowly but surely ascending to the surface, assisted by a thread fixed to the leaf or other house prop below, and to the outside of the water, she obtains a bubble from the atmosphere, and immediately and quickly descends with it by the same route to the bell-shaped nest. Having arrived there, she disengages the air. These journeyings are repeated perhaps fourteen times, and at last her apartment becomes full of air to the exclusion of water, the globules of air having replaced the water. Into the dome she enters, and settles to rest, undisturbed by the agitations above, head lowermost, after the manner of her tribe. The air acquired is mechanically entangled in the tissue covering the animal's body, and is held on by the two hinder legs, which are crossed over the abdomen at the instant that the bubble is seized. To this home the spider brings

her prey, and in it lays her eggs, spinning a white silken saucer-shaped cocoon for them, and placing it against the inner side of the cell and near the top. The young remain beneath with their mother until they are grown a little, and have become strong enough to form sub-aquatic dwellings on their own account.

The so-called raft spider (*Dolomedes fimbriatus*) is amongst the largest of the British species, and the globular cocoon, which the female carries about with her, may contain as many as several hundreds of eggs. The spider not only lies in wait for its prey, but chases them like a carnivorous vertebrate.* It pursues them on land, and in the water, on the surface of which it runs fearlessly. When thus employed it gathers a quantity of dry leaves and rubbish, and unites the collection together with threads of silk into a resting-place or raft. On this the maker sits, and is blown about by the winds and currents It knows no lack. Aquatic insects are constantly coming up to the outer air to breathe, insects just completing their transformations are acquiring their wings at the surface, and many smaller and less powerful than our hunter are abroad on the water on the same errand, to gain their livelihood. Any and all of these make capital food for fimbriatus, who pounces upon them, and devours them on the raft. Should it see an enviable morsel at a distance it darts off the platform, returning to enjoy its meal. On the

approach of an enemy it can penetrate the water, and can exist submerged for some time.

Lycosa piratica, a closely allied species, also chases its prey on the water, but it makes no raft. It likewise is able to descend below the surface, when it breathes by means of air confined among the hairs with which it is clothed.

CHAPTER IV

SOCIAL HOMES

Diversity of method of insect architecture, its beauty and size — The word architecture as applied to this portion of insect economy — Societies of social caterpillars — Three types of nests of ants — Home of Common Wood Ant — external conformation — internal plan — doors — formation and regulation of society — A solitary "queen" as founder of a colony — Singularity of wood ant in preference for open-air life — Mason Ants — Extraordinary dimensions of homes of Saüba or Coushie Ants — Their leaf-cutting propensities — Mushroom-growers — Mason Ants of New World; their disks, roads, refuse-heaps, store-rooms, nurseries, lumber closets, position as farmers, &c. — *F. fuliginosa* and other carpenters — Standing-army of Bull's Horn Acacia — Ants as guardians of other plants — Remarkable pensile nests of *Crematogaster*, *Myrmica Kirbii*, *Œcophylla smaragdina*, &c.

In no branch of insect work are more admirable means employed to bring about the desired ends, or is greater diversity of method found, than in that of insect architecture. The beauty of the buildings in many cases is incomparable, and generally speaking the abodes attain a magnitude colossal as compared with that of their creators. It may be exception will be taken to the use of the word architecture to designate this portion of the insect economy, and perhaps the term can

hardly be applied in fairness to homes which are mere tunnels and galleries bored in the earth or in wood. But who would deny it to the exquisite pensile nests of the English wasps, or those of many a foreign relative, to the geometric precision exhibited within the hive of the honey-bee, or to the edifices of some ants, as will be presently discovered.

Among the communities which combine their operations, there are those of which the object is simply the protection of the individuals composing them. To these societies belong the caterpillars of certain species of moths. The homes formed by these larvæ, though they are not elaborate, are interesting in several minute circumstances. But they fall short in every respect of the attractive nests fabricated by companies of insects in their perfect state, in view not only of self-preservation, but of the nurture and education of their young as well.

Of these the nests of different kinds of ants are the most simple in their character. None the less on this account they are worthy of investigation, owing to dissimilarity of design both in outward form and internal plan, on account of the materials composing them, and the manner that they answer the wants of the species. Their size is astonishing, and outrivalled only in the inferior departments of the animal kingdom by the works of the coral animalcula. They may be formed with earth, and

consist either of excavation under ground, or of excavation combined with building on the surface. Their makers may be called masons. Ants are likewise carpenters by trade, hewing their homes out of solid tree trunks and roots often with an excessively involved and delicate art. A third kind of nest is pensile, and composed of leaves, or of collections of vegetable or animal matters. These three general types include many most interesting modifications, each species of workmen being endowed with the operative talent that suits them best.

The common Wood Ant, otherwise named the Hill, or the Horse, or the Red (*Formica rufa**), is a good representative of the group (Formicites*) to which appertain the true ants. Few people in this country, and throughout all central Europe, are unacquainted with the dwellings (see Fig. 15). They consist exteriorly of elevated hillocks or mounds, many of them of large dimensions, made up of bits of straw, wood, little stones, morsels of earth, leaves, grain, in a word, of anything portable and within reach. Usually they are situated in woods or their neighbourhood where the undergrowth is not too dense, often under some shelter such as a bush or tree. They are especially plentiful in fir-woods, where the fallen needle-like leaves of the firs afford abundance of building material ready to hand. At the first glance the dome seems nothing but a rude confused mass;

in reality its internal construction presents an arrangement that is excellently adapted to pro-

Fig. 15.—Section through a typical nest of *Formica*; after Smith.

mote the welfare and comfort of the inhabitants, ensuring them free liberty of action throughout,

and protection at once from extremes of heat and cold by the maintenance of a genial warmth. It is composed of numberless small chambers, united together by galleries, in order a series of flats or stories; besides these there are more or less irregular avenues communicating with the outside. In fact, the fragments, instead of being thrown down confusedly and without purpose, are carefully disposed after a definite though not very regular plan. The beams are piled ingeniously, and their interstices in some parts of the nest are filled up with earth, grains, and scraps of dried leaf, giving strength and solidity to the whole mount. It is worthy of note that the longest sticks are reserved for the galleries, in order to prevent by every possible means the materials from falling in, and causing interruption in the routes of communication. Due to this orderly method of erection the domes can withstand the shocks both of rain and wind, without being penetrated by the one or blown away by the other. The nest is completed by a corresponding labyrinth of chambers and galleries in the ground, from which mining system the earth granules utilised in the upper fabric are obtained.

To all appearances the entrances to the galleries from the outside are exceedingly ill-fitted for the exclusion of damp and of nocturnal intruders on the ants' privacy. The openings exist at the owners' pleasure. In the early morning they are

nowhere visible, and the nest is as though deserted; or a few small cracks are apparent, whence issue forth some workers betimes. By-and-by, as the day advances the passages are swept and cleared, and the holes are made for the day, while the entire population become actively engaged in their several avocations. Only if the day be fine, however. Should it rain the portals are kept fast, or if the sky be cloudy they are partially opened. The drawing in of night sees them wholly closed, when all the inmates gradually retire to the interior to enjoy rest from labour, confident of peace, a few sentinels being left to guard the gates. Should a brilliant morning and consequent wide-flung doors be succeeded by heavy showers, the ants hasten to prevent catastrophe by the re-establishment of the barriers, and every member appears willingly to give its quota of help to speedily accomplish the work in hand.

The formation of a nest may be traced from the beginning by brief close investigation into the state of society of a large community during the early months of summer. Here, in addition to the presence of the vast multitude of wingless worker ants, and some females now in like condition, a certain number of young winged males and females are all ready and eager to escape from home. Soon after their birth, taking advantage of a favourable opportunity, usually on some warm still afternoon, they adventure out. Some of the females, or so-called

"queens," are compelled to return, and having torn off their wings, which are no longer of use, with the assistance of the workers, they settle down to an unintermitting sedentary existence, replenishing the population of the only abode they will ever know. Other females while in this comparatively helpless condition are conveyed by workers to new situations, where they become the founders of new colonies.

In effecting the establishment of a colony, the little company at first betake themselves to mining. With their mandibles they set arduously to work, until by dint of prolonged and strenuous labour a cavity in the earth is formed. Meanwhile some of the future inhabitants of the nest may be seen wandering about the vicinity in search of building-stuffs for the exterior. Scrap after scrap is gathered, and laid over the entrance to the hole, one piece being crossed over the other, while the lowermost bits are stuck into the earth so as to fix the foundations of the aerial erection. Many of the little creatures are equally busy in mingling the vegetable morsels constantly brought in by their fellows, with the grains of earth thrown up in hollowing the underground apartments, tempering the granules with rain water, which harden in the sun and effectually bind together the different substances. Thus do these fragile materials, without cement and not even interwoven, constitute a tolerably firm composition, one able to withstand the

weather, and the bustling energy of the ants in their life's occupations. Day by day the stories composed of chambers, cells, large and small, and passages, are superimposed upon one another, and the edifice increases in size, cavities being left open throughout the day as the work proceeds, where the builders intend to construct the galleries which are to lead to the interior.

During the first fine days of the year the eggs begin to be laid, and from this moment until as perfect insects they are fully competent to "do" for themselves, the young become the objects of tenderest solicitude to the nursing ants. Placed alternately in the recesses and the outer chambers of the nest, — in the first at night for warmth, whence in the morning they are removed to the upper rooms where the sun's heat penetrates, so as to be maintained at a uniform temperature, — gradually under this fostering care the eggs increase in bulk, and the larvæ are hatched. Now even more than formerly, the little ones demand attention. In addition to change of room every morning and night, and frequently at shorter intervals, in consequence of sudden alteration in weather, as an unlooked for shower, which will cause the workers to hurry their charges away from the surface to the inner depths, or should the sun become too hot in the day cells, — the rapidly developing nurslings have to be vigilantly cleansed and fed. When full grown the majority of ant-

larvæ spin silken cocoons around them. In this state they are well known, and collected as food for young pheasants. Popularly they are termed ants' eggs, but how the egg could exceed the size of the insect that laid it is a problem that never seems to suggest itself to the nomenclators. The pupæ, like the larvæ before them, are carried by the workers from room to room, and for the same purpose. Eventually their metamorphoses are

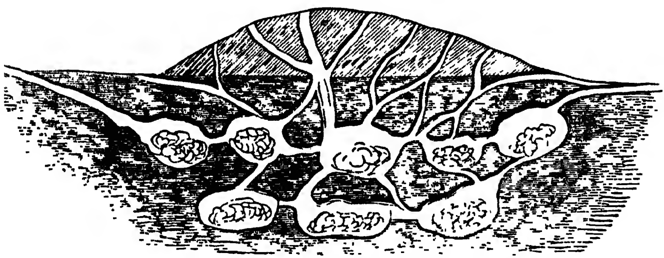

FIG. 16.—Section through the nest of the Leaf-cutting Ant *Œcodoma cephalotes*; from Belt.

almost complete, still the nurses do not dare to relax their attendance upon them. Without assistance the immature ant is incapable of freeing itself from its covering, and would perish miserably, ere it can be said to have really lived. The workers, observant of the right moment, tear open the cocoon with their mandibles, and set free the now perfect creature. For a little while it is weakly, and unable to take care of itself, and assume its share of the tasks of the hive. So long as feeble-

ness continues the nurses never lose sight of their tender dependant, they watch it until strength and knowledge of its duties are acquired. The affectionate workers even accompany their young winged nurslings to the surface of the dome, and feed them for the last time before they start, in turn, on their nuptial flight.

On the occasion of this swarming, which has been already alluded to, it was formerly thought that when any female alighted at a great distance from the nest, driven thither by the wind, or carried merely by flight, she found her way back to her original quarters. This has been proved to be impossible. On the contrary, a solitary female falling to the ground in an out-of-the-way spot, has been observed to creep into a hole, and to cast aside her wings, and with them her dignity, as it were, and usual exemption from toil, taking upon herself unaccustomed menial offices. Alone, unaided, she constructs a small nest, and lays some eggs, and feeds the young, and rears them to maturity. Wonderful to say, she appears to be aware of the necessity of developing them into workers. No sooner do they attain perfection and the capacity to assume adult labour, than the mother relinquishes the duties foreign to her nature, and falls back on the sole occupation of egg-laying; leaving her progeny to enlarge the dimensions of the dwelling, to keep it in repair, to defend it, to provision themselves and her with

food, and to act the part of nurses to the young, with which she continues to stock the colony. Subseqüently these include among them winged males and females.

The wood ant is singular in having preference for an open-air life during the heat of the day, and is continually on the outside, seeking for food or employed on the exterior of the dome until dark-

FIG 17. — Saüba or Leaf-cutting Ant carrying leaf; from Bates.

ness compels it to desist. It is seemingly fearless of being surprised by enemies, at least during the day, and does not construct a long covert way to its nest, as if for concealment, like the yellow and brown kinds. But the wood ant never fails in its precaution against attack and assault of the dwelling by night, and when business must be completed after dusk, it is done with shut doors. The actual manner of obliterating the apertures is

noteworthy. To the entrance of the avenue which the ants desire to close, beams are brought forward and deposited in the stubble; similar morsels are placed above but in another direction, and pieces smaller as the work proceeds. At length bits of dried leaves and other materials of larger size are laid down; the exact art in miniature of carpenters when roofing a house. Nature seems everywhere in advance of those inventions of which we as men are so proud. Doubtless had careful observers of these things existed in early times, many mechanical devices which have taken civilised nations centuries to discover and to perfect, would have played their part in the world's history considerably sooner than they have done in fact.

The nests of *F. rufa* are particularly large in the fir-woods of Scotland, where I have seen them the size of small haycocks, and occupied by absolutely countless numbers. Yet these are mere mole-hills as compared with the enormous mounds of species, apparently of the same family, in warmer climates. Stedman speaks of ant-hills in Surinam over six feet high and at least a hundred feet in circumference; Malouet mentions having come across specimens in the forest of Guiana of a height that he computes at fifteen or twenty feet, with a diameter at the base of from thirty to forty.

Although the architecture of most ants is possessed of strong points of resemblance, each species chooses a particular position for its nest and estab-

lishes it on its own plan. Like *F. rufa*, many that work in earth are admirable subterranean burrowers. Perhaps the brown, *F. brunnea*, carries off the palm, a species not very common in this country. Though one of the smallest, it is remarkable for ingenuity and the beauty of its finished workmanship. The nest consists of series of stories, sometimes not fewer than forty, twenty below the level of the soil and as many above, which last are not horizontal, they follow the slope of the ant-hill, and lie one upon the other to the ground floor, presenting the appearance exteriorly of an elevated dome-shaped mound. Each story, separately considered, is composed of cavities, narrow chambers, and long galleries which preserve communication between both. All are smoothed as though with a plasterer's trowel, and are about the fifth of an inch high. While some of the more spacious rooms have only one entrance from above, or in addition a second leading to the story lower, some are large open spaces, being in fact the points where meet several of the main galleries, a kind of cross roads, and are connected with subterranean passages frequently carried to a distance of several feet from the hill. The arched roofs of the chambers, which are often more than two inches across, are supported by excessively slender partition walls, or by small pillars and true buttresses. The building material consists of soft clay excavated from the bottom in mining, and is often moist

enough, since the sun cannot penetrate to the lower depths. Were the supply taken from the surface, business would be practically at a standstill during dry weather.

To enable him to watch these ants, Huber had a carefully arranged contrivance constructed, a sort of vivarium, where the insects were furnished with the conveniences to prosecute their ordinary work. While some might have been seen busily engaged upon the soil, kneading and moulding it with their mandibles into ductile pellets, an action analogous to brick-making, others were as diligently scooping out shallow cavities in the clay floor, the ridges that were left being the foundations of the future walls. On these pellet after pellet prepared for use were adjusted, and spread firmly and evenly, greater compactness being obtained by light pressure of the ants' fore-feet. However numerous the masses may be, the walls when finished look uniform and unbroken. Openings are made where necessary in the masonry to admit of communication, and when the two walls of any gallery or chamber reach the proper height the space between them is covered in by the ceiling. The method of construction is to mould pellets into each angle of the apartment, and also to the top of the pillars, extending the roof by successive layers of pellets, as fast as one row becomes dry a second being added until the approaching sides meet.

No glutinous matter is introduced into the masses

of clay by way of mortar or size for consolidating or strengthening the building. The particles adhere merely by juxtaposition, the peculiar kneading and biting to which they are subjected rendering them very tenacious. Moisture, however, is absolutely necessary to the ants, and if deprived of it in the shape of gentle showers, or if the clay from below is not properly damp of itself, they abandon

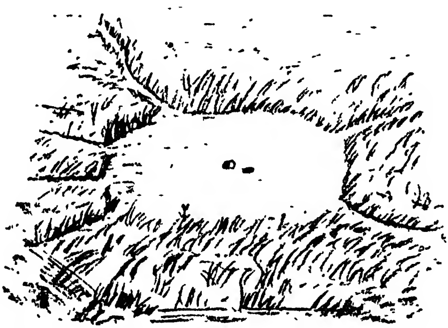

FIG. 18 —Agricultural Ant of Texas (*Pogonomyrmex barbatus*). Large flat circular disk and open roads made above the subterranean formicary; from McCook.

their labour as hopeless and wait patiently for rain. In the event of the continuance of dry weather, they pull down again the crumbling apartments that are not covered in. As regards the ants kept by Huber in captivity, he found that whenever they ceased to build he could almost always induce them to resume by dipping a brush in water, and striking it with the hand, so that the fluid fell like

fine rain. As soon as they felt the refreshing drops they would immediately regain their activity. Much wet is as inconvenient to them as a drought. But when their walls are complete they are very strong, and extremes of heat and moisture appear only to increase the cohesion. These insects avoid the sun, and seem to work chiefly at night and during light misty rain. Wonderfully assiduous, they have been known to construct a story, with all its saloons, vaulted roofs, partitions, and galleries, in from seven to eight hours.

FIG. 19.—Agricultural Ants cutting down obtruding grass; from McCook.

Two other masons common over a great part of Europe, the ash-coloured or dusky *F. fusca* * and the so-called mining ant, *F. cunicularia*, form similar nests, but the last-mentioned makes no dome. Both are probably less particular in the selection of their building materials than *F. brunnea*. The hillock of the ash-coloured ant always presents thick walls, the stories are well marked, the chambers large with vaulted ceilings, and the galleries, strictly speaking, are large oval passages. The chambers

and galleries rest upon a solid basis, arising from the mode of heightening the habitation. The existing roof is covered with a thick layer of fresh moist clay, converting it into a floor for the proposed story. On this the builders proceed to plan the erection intended, forming cavities of almost equal depth in it, and raising the intervening elevations into wall-like partitions, having first reduced the foundations to a due thickness and removed the loose earth from the floors of the apartments. Lastly, all is closed in. The muscular power and energy of these ants are truly amazing, as exemplified by the observations of Huber, who watched a single worker make and roof in a gallery two to three inches long, she herself fetching, and kneading, and placing her own materials, and the interior was rendered perfectly concave, a day's work, in proportion to her size, far beyond the power of man. This ant prefers a nest-site with southern aspect.

The Saüba or Coushie ant (*Œcodoma cephalotes*), peculiar to tropical America, is a mason that exceeds the European species in the magnitude of its labours. Its nests, found in plantations and woods, consist of dome-like edifices elevated over underground earthworks (see Fig. 16). The domes differ in colour from that of the surrounding superficial soil, owing to being formed of earth brought up from a considerable depth. Frequently no less than forty feet in diameter, with a height of two feet, measurements simply gigantic having regard to the builders,

they dwarf into utter insignificance the mightiest efforts of man, the relative dimensions of the workers being considered. But though the domes are immense, they are as nothing compared with the limits of the underground galleries, which are often of almost incredible extent, and show no trace of their presence, and suddenly the ants will come to the surface where least expected. So vast are the subterranean passages and so complicated, that they have never been thoroughly investigated, but an

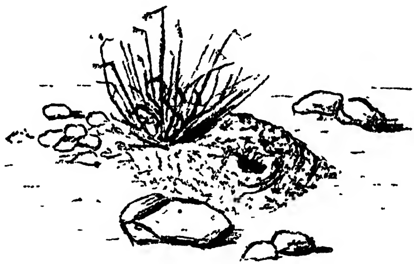

FIG. 20 —Gravel cone nest of Honey Ant built partly round a tuft of gramma grass; from McCook.

idea of their size is obtained from the fact that once when sulphur smoke was introduced into a nest it issued at an outlet seventy yards distant. Mr. Bates relates that a species has been known to excavate a tunnel under the bed of the river Parahyba, in Brazil, at a place where it was as broad as the Thames at London Bridge. Galleries radiate from the dome in all directions; the nest also contains rounded chambers about as large as a man's

head. The entrances are small and numerous and generally closed; very rarely the ants are seen at work upon the mounds.

Popularly known as leaf-cutters, these ants are a veritable scourge in central and tropical America, where they abound, and may constantly be observed forming broad processionary columns on their way to and from the scenes of the fearful havoc they commit, persistently and laboriously abstracting quantities of pieces of foliage from the trees as large as sixpenny bits. Valuable cultivated plants suffer most from their attacks, the orange, lemon, coffee, and mango especially. In some districts agriculture has been rendered almost impossible in consequence, or has been abandoned. Their mode of cutting off the bits of leaves is very interesting. Equally attractive are the insects when in order of procession, returning home laden with their spoil like multitudes of animated leaves, each workman marching along holding its portion in its jaws erect by one of the edges. The habit has obtained for them the name of Parasol Ants, the burden being supposed to be carried to shield its bearer from the sun (see Fig. 17). It is now ascertained that the gleanings are minutely subdivided and stored in the formic chambers until decayed. On the rotten mass grows a minute white fungus on which the ants feed; they are in fact mushroom growers and eaters.

Great interest is attached to certain mason ants

of the New World, the so-called Agricultural Ants of Texas and Florida and the Occident Ants of the American plains. The formicaries of *Pogonomyrmex barbatus* are scattered over the light soil on the hill slopes of Texas, in the deep dark earth of the highlands and valleys, among the rocks, indeed almost everywhere. Externally they are for the most part flat, smooth, circular disks in the

FIG. 21.—View of the nest of a Provident Ant (*Atta barbara*) from Mentone, showing a granary excavated in rock and the conical refuse heap

midst of surrounding herbage, presenting the appearance of miniature "clearings" in the American backwoods (see Fig. 18). Some of them are as large as from seven to twelve feet in diameter, the average ones reach a diameter of only four or five feet, covering a space of from twenty-one to thirty-six square feet. From this central platform, as it were, broad and similarly clean paths or avenues branch off into the encircling vegetation, they

gradually narrow, and almost imperceptibly blend with the vacant spots between tufts of grass. In number these paths are usually three or four, sometimes there are as many as seven, with a width at their entrance upon the disk frequently of two and a half to three inches, occasionally enlarging to five or six. A hole within the disk leads to the subterranean regions, which include store-rooms for the seed, nurseries, and other chambers, their arrangement being more or less in stories.

Extraordinary must be the labour on the part of these insects in effecting the removal of the rank vegetation of the country from the bounds and approaches of their nest. The weeds stand in a well-nigh perfect circle around the circumference of the cleared space. Tufts of grass, wild sage, the daisy, and such-like sturdy growths are there, with stalks at times as thick as one's thumb, and over two feet high. The plucky beings appear to bite, and saw, and twist, and tug at the leaves and stems until they are severed and can be borne away (see Fig. 19). Presumably, the avenues are denuded in similar fashion. During the winter months, when many of these ants retire under ground, the clearings fall into sad disrepair, and the weeds intrude, to be as vigorously expelled in the following spring, when warmth once more recalls the workers to set all things in order. The use of the pavements is doubtless to facilitate entrance to, and exit from, the home, so as to reduce

the fatigue inseparable from toil. The avenues are made with like intent, enabling speedy and ready journeying to the harvest grounds and back. The exertion involved in searching for the wished-for plant-seeds, in adjusting them for convenient carriage, and in bearing the weights, is remarkable considering the size of the workmen at their calling, and amply justifies them in lightening their labours by every means in their power. The seeds are stored in large quantities, entire as gathered, and also stripped of their shells, and are believed to serve the gleaners as food during their confinement in winter. Refuse heaps, consisting of the discarded shells and glumes,* are raised outside, and have been facetiously termed the kitchen-middens. On opening some of the nests in spring the granaries are discovered to be not nearly so well stocked as in the fall, a fact that argues strongly in favour of the actual consumption of the seed.

As the season advances, and autumn once more deepens into winter, while some disks continue to be kept free of herbage of every description, many of the platforms become partially covered with a row of one particular plant, the *Aristida stricta*, or "Ant Rice." The circular cluster is strictly limited by the outer bound or circumference of the clearing, beyond which grows the ordinary wild grass of the locality. It ripens by the ensuing spring, and there seems little doubt that from it the ants

then gather in a harvest of seed, subsequently cutting down and removing its dry stubble, along with any weeds that have trespassed on the private property during winter; leaving the "pavement" again unencumbered until autumn, when the same favoured plant once more presents itself. It has been urged that the needle grass is deliberately sown by the ants on the cleared ground in summer, and is cultivated with the intention of reaping a crop from it in the following spring. It seems hardly possible to credit them with such wisdom. Nor on the other hand, as the opponents of this theory believe, is it likely that they are overtaken by the autumn "rice," and are unable to prevent it, since surely the power which enabled them to eradicate all usurping winter growth from their domain in spring, would admit of them keeping it clear. Besides, the exclusive occupation of the disk by this grass, so long as the ants are up and about, counts in favour of voluntary action on the part of the insects. Probably the Aristida is seeded yearly in a natural way by droppings from the plant, or from seeds dropped or cast forth by the ants; and the ants find it to their advantage to permit and foster the ensuing growth, because of greater convenience of harvesting the seed, while, farmer-like, they expel all other vegetation from their precincts.

In some instances the central clear space is occupied by a low mound, in shape somewhat like a

volcanic cone with a crater-like depression at the summit. A distinct flat bare belt or zone may exist between the mound and the margin of the

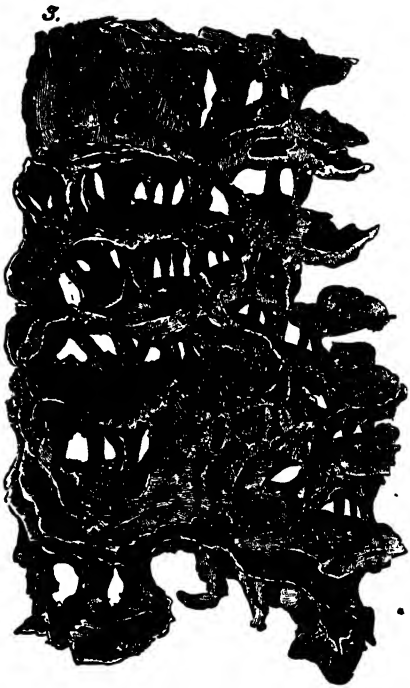

FIG. 22. — Fragment taken from the trunk of an oak inhabited by Fuliginous Ants; from Huber.

nest, of no great width; or the grass of the surrounding prairie may grow up to the cone's base. The material composing the mounds is a light sandy soil. Other nests have gravel disks. Round the

opening to the underground apartments is a mass of gravel, which may accumulate into a little heap, and beyond extends the smoothed belt of ground with circulatory margin. Entrance to the interior is by one, two, or more gates; apparently the tendency is to increased numbers in nests with cones and mounds. Immediately within the gate is a vestibule, smooth, and from one to two inches wide, which, at a distance from the entrance of from half an inch to two and a half inches, diverges into tubular galleries connected with the granaries and nurseries. In general these rooms are circular, oval, and crescent-shaped. The depth to which they are carried probably varies, but nests have been excavated as far as four feet below the surface and no termination of the mining was reached. Rooms even at two and a half feet down are packed with seed, and narrow gangways are left at the outer margin between the grain-heaps and the wall. The elevations upon the disks are used for habitation, and are not simple accumulations of earth excavated from the underground cells and galleries. The architecture of the Florida harvester (*P. crudelis*) is in close resemblance to the cone structures of the Texan agriculturist.

The nests of the other known North American congener of Pogonomyrmex, the Occident Ant of the great American plains (*P. occidentalis*), are similar in exterior to the gravel-covered cones of

the Texas and Florida harvesters. They form conspicuous objects upon the level plains, or gently sloping hills, alike by their elevation and their great numbers. The cone rises to a height rarely exceeding ten inches, though it appears much more, owing partly to the situation. It generally

FIG. 23.—*Pseudomyrma bicolor* inhabiting *Acacia cornigera.*

stands in or near the centre of a round or elliptical pavement or clearing, but no crop of "rice" breaks its monotony; it is always totally freed of vegetation, unless it be for an occasional tuft or blade of grass straggling here and there. Its use then differs from that to which the Texan nest-

space is put, since it is no harvest-field. Its advantages, however, are manifest. By it the ants gain easy ingress and egress to and from their home when pursuing their daily tasks, obviating the toil unavoidable had the way been obstructed by plants. Vegetation in the immediate vicinity of the nest is likewise highly dangerous, in that it affords concealment to enemies at close quarters. It may be also that plants, seeing that they harbour damp, would be injurious to the young; and the roots might penetrate to the interior of the home and cause damage and inconvenience. The well-established and ordered roads between the formicary and the harvest-grounds, so characteristic a feature of the Texas communities, are absent, a fact that perhaps reflects to the credit of the ants in question. For while the vegetation surrounding the clearings of the Agricultural Ant is dense, and pathways through it are an advantage, if not a necessity, generally on the American plains where the Occidents occur, the Gramma Grass (*Bouteloua oligastachya*) prevails, which grows in tufts or bunches separated from each other by several inches, and the intervening spaces present only a smooth level soil, so that specially made roads are uncalled for.

The cone is covered exteriorly, roofed, as it were, with a coating of pebbles to the thickness of about half an inch, not, or but sparsely, intermingled with the soil below, which is chiefly the nat-

ural soil of the surface, and constitutes the bulk of the mound. The stones are obtained from the subterranean galleries and chambers, whence the miners bring them up and distribute them on the top of the cone. These objects are of enormous weight as compared with that of the carriers, and their transportation from the interior beds to the outer atmosphere, by way of the sharp slopes or almost perpendicular surfaces of the galleries, must be a formidable task. The entrance or entrances to the dwelling, unlike those to the cone nests of the Agriculturalist, are not in the crater-like depression on the summit, but in the side of the cone and near the base. In width they vary from about three-quarters of an inch to three inches at their mouth, they are quite shallow, simply penetrating through the gravel to the inner soil. They open into the vestibule, and from it one or more galleries extend downwards through the cone, and communicate with the intricate system of passages, store-closets, nurseries, and living-rooms, mostly all situated beneath the level of the surface of the ground. The Occident also shuts its gates in the evening, and on the occurrence of a storm; it re-opens them late in the morning. Its labours it confines to the daylight hours.

In form and plan the interior follows closely that of the Texas Agriculturalist; in fact a striking resemblance in this respect exists among all these ants. The rooms, mere lateral expansions of the

galleries, measure at most about three and a half inches in width, their greatest length is about five or six inches. The galleries are cylindrical, and of various lengths, and rarely exceed a diameter of half an inch. The apartments seldom extend beyond the limits of the "clearing," and chiefly underlie the cone itself. Dr. McCook ascertained that they descend to a depth of between eight and nine feet! Many of them are granaries; a single room has been found to contain seed to the amount of two tablespoonfuls. These deposits seem to clearly prove the harvesting proclivities of the Occident Ant, and beyond doubt the harvest is reaped for food. Dr. McCook, when engaged in examining these formicaries, came upon rooms packed full of gravel, a circumstance attributed by him to a division of labour among the ants in their herculean mining. He conjectures that it is here the pebbles are carried by those labourers who cut them away from the soil in which they are embedded, when making the deep chambers; while a second gang thence transports them to the upper regions, and arranges them upon the cone. Some, however, Dr. McCook says, were not simple dumping-rooms to prevent stagnation of work, but veritable lumber-rooms, emmetonian garrets, for they had evidently contained the gravel for a length of time, and were apparently sealed up in the very midst of the nest.

The nests of the honey-storing ants of Mexico

likewise consist externally of gravel-covered cone-shaped mounds, of diminutive proportions, attaining a height seldom more than about three inches (see Fig. 20). A single narrow tubular entrance-way descends through the mound and the earth more or less perpendicularly, to a distance varying from three and a half to six inches, and opens into the underground rooms and galleries. Arranged in several horizontal series one above the other, and intercommunicating by vertical passages, these extend chiefly in one direction from the gate. This ant is nocturnal in its habit of foraging for food, but does not bar its door in the daytime, the plan adopted by a night-wandering ant of Texas (the Cutting Ant, *Atta fervens*). The Honey Ant, however, does not neglect measures for safety; just within the margin of the opening cordons of sentinels are stationed continually, whose business is to keep a sharp look out for enemies, and they appear to hold themselves in readiness during storms to repair damage or disarrangement of the pebbled roof. Disaster from this cause is slight, owing probably to the admirable choice of the situation for the nest. The honey-rooms, the abodes of the inflated honey-bearing individuals, are oval, conspicuously large, and vaulted, and will sometimes rise from a height of barely three-quarters of an inch at the walls to an inch and a half in the centre. The galleries are smoothed throughout; but while the floors and walls of the honey-rooms

are pressed well-nigh invariably, their ceilings present uneven surfaces, being in fact the natural condition of the soil after the sandy pellets and pebbles have been abstracted by the workers. The evenly-spread earth is adapted for gangways; the rough-

FIG. 24. — Nest of a Tree Ant (*Œcophylla smaragdina*) from India

ness of the ceilings enables the honey-bearers to cling to them as to a perch.

In the homes of the Harvesting Ants of Europe (*Atta structor* and *barbara*) elevations above the soil are wanting. The large mounds frequently

seen at the entrances are rubbish-heaps, the kitchen-middens of the establishments (see Fig. 21). Earth pellets and grains of gravel brought out in forming the subterranean galleries occur in the heaps; but they are composed principally of plant-refuse, such as the discarded envelopes of seed and grain, the chaff of grasses and the like, of which it is advantageous to get rid, in order to obtain greater space for the storage of the good food. The workers relegated to the duties of sorting the supplies, and casting forth those portions that they find to be useless, must labour with assiduous energy, judging by the speedy rise of the middens in the harvest season; and where their position is sheltered from wind and rain, they often acquire considerable dimensions. On and about these accumulations, plants foreign to the immediate vicinity sometimes flourish, having grown from seeds accidentally dropped by the ants on their way home from the harvest grounds. The texture of the floors of the storechambers usually differs markedly from the surrounding soil. The horizontal rooms at times lie at great distances apart, but where the soil is shallow the galleries and granaries may be much crowded together.

Some ants live in trees, and cut and chisel the wood in a wonderful manner. The best known is *F. fuliginosa*,* the emmet or jet ant, a brilliant black insect with pale reddish tarsi.* Its residences it constructs in the interior of old oaks and wil-

lows, gnawing the trunks into numberless stories always more or less horizontal, with a distance of about five or six lines between the ceilings and floors. The divisions are scarcely thicker than paper, a delicacy that is also attained in the vertical supports that apportion off the separate chambers. Communication in each story is by small oval apertures. In some cases the walls are reduced each into two pillars, rendering the apertures larger and rounder. When the work is still more advanced the holes become square, and the pillars originally arched at both ends are hewn into straight regular columns, giving a palatial aspect to the excavation. Further progress transforms these partitions into light cylindrical columns possessed of a base and capital which are arranged in colonnades, leaving a free communication throughout the whole extent. The rooms on or about the same plane when complete necessarily form a story, but since they are hollowed out separately, though on similar plan, and the sides are chiselled away as time goes on, saving material sufficient to sustain the ceilings, the flooring cannot possibly be very level. This seems a boon rather than a disadvantage, for the irregularities appear to answer as cradles for the larvæ. In roots sometimes, as in Australia, the nests look like charming net-work. The material carved becomes black, as if smoked, due to exposure of the wood to the atmosphere, to some emanation from the ants, or to the action of formic acid (see Fig. 22).

Wood-carving ants also infest the beams of houses, and imperil their safety.

Two other tribes of Carpenters, *F. æthiops* and *F. flava*, the yellow ant, have the ingenuity to utilise the saw-dust that they chisel away. The former applies it to stopping up chinks and to the building of walls; the latter, more skilled and inventive, composes entire stories of it stiffened and cemented into a kind of *papier-mâché* with earth and spiders' web.

Curious Carpenter Ants (*Pseudomyrma bicolor*), if so they may be termed, inhabit the strong curved spines of the Bull's Horn Thorn, a species of acacia, so called because the branches and trunk are covered with spines, set in pairs, which bear great resemblance to the horns of that quadruped. When the thorns are first developed, and are ready for tenancy, they are soft and filled with a sweetish pulpy substance. It the ants eat away, preserving the hollow hardened shell, within which they live and rear their young. Near the tip of the thorn an aperture is made for entrance and exit. Additional doorways are not required, the partition separating the two thorns is burrowed through, so that one opening serves for both (see Fig. 23). The acacia does something more for the ants than provide them with lodging and a stock of food with which to commence to keep house. Its leaves are bi-pinnate,* and at the base of each two leaflets on the mid-rib a crater-like gland when the leaves are

young secretes a drop of a honey-like liquid of which the ants are extremely fond, and they constantly run from one luscious mass to the other, sipping greedily. Nor is this all, — the tree likewise provisions its guests with solid food in the shape of yellow fruit-like bodies, one at the end of each of the small divisions of the compound leaflets. Examined through the microscope they look like little golden pears. When the leaf unfolds the fruits are not quite ripe, and the ants are continually watching and investigating their progress. Finding one sufficiently advanced they bite through its small point of attachment with the pinnule,* and, bending it down, break it and bear it off to the nest. Like the glands the fruits do not ripen at once, but successively, keeping the ants in protracted attendance upon the new leaves.

In this way the formic visitors are brought to act as the standing army of the acacia, at the season of the year when it is fresh and sweet and most liable to attack, in return for all the comforts and luxuries that it bountifully affords. Provided with severe stings the protectors preserve the leaves from the browsing of mammalia, and from the ravages of much more dangerous enemies, the leaf-cutting ants; nor can a caterpillar venture to approach without suffering from the weapons of the plant's body-guard. Even should the aggressor be man, and if he touches or shakes a branch, they swarm out, making free use of their jaws and sting.

To all appearances they lead the happiest of existences. They fear no foe, they have ample food, and accommodation all that heart could desire. But there is a reverse side to this happy picture. In the dry season on the plains the acacias cease to grow, no young leaves are produced, and the glands, now old, secrete no delicious honey. Then the ants perish miserably from want and hunger, and many of the thorns become depopulated. Again, when the rains set in, the buds burst forth with all their dainties to the ant palate, and accordingly once more the creatures multiply.

Both in Brazil and Nicaragua the flower-buds and young leaves of numerous plants are exempt from the destruction of herbivorous insects and mammals through the presence of their honey glands, whose primary object is to attract the guardian ants. Among others many epiphytal* orchids and species of *Passiflora* may be mentioned, but they provide no house room for their warders. On the other hand the *Cecropia*,* or Trumpet Tree of Central America, equips ants with a house, but no food. The absent necessary the tenants furnish themselves with by means of *Coccidæ*, or scale insects, which they introduce into their home, and keep in their cells within the tree. From these lodgers a sweet liquor is obtained, and the Cocci in turn find their nourishment in the plant's juices. The stem of the Trumpet Tree is hollow, and divided into cells by partitions which extend across

the interior of the trunk. The ants gain admission by boring a hole from the outside; subsequently they pierce the partitions and get the run of a large space. In her own royal cell the queen of the community resides, surrounded by a special bevy of Cocci, who yield her the requisite sustenance. The eggs, the grubs, and the pupæ, have likewise their private apartments. In some of the *Melastomæ* ants occupy the pouches on the petioles * at the bases of the laminæ. As in the previous instance, *Coccidæ* are taken for the supply of food. The hosts, on their part, guard the leaves in return for shelter, and shield their attendant *Coccidæ* from the attacks of other animal forms in the common habitation.

Unfortunately many of the exotic ants have been only slightly studied in respect of their habits, and their remarkable architecture has been allowed to pass without the investigation that it merits. Among kinds neglected must be included species of *Crematogaster*. When these run about they hold their abdomen high in the air, so that it curves backwards and overhangs the thorax, whence is derived their title signifying "hanging-belly." In the Brazils a species popularly called the Negro Head makes a strange nest, as round as the negro's bullet-shaped head, and exteriorly covered with projections, suggestive — with a little stretch of the imagination — of the African's close woolly hair. It is pensile on trees, and might easily be

mistaken for the pensile home of certain wasps. Its internal arrangements prove to be more elaborate, for it is ramified with multitudinous covered passages interlacing intricately, but all leading to the interior cells.

Formica elata and *Myrmica kirbii* also carry their abdomens erect, and both build on the branches of trees and shrubs. The nest of the former is a wonderful construction of earth mixed with leaves, which in some cases are exchanged for minute vegetable hairs. *Myrmica kirbii* makes a habitation of a congeries* of the excrement of cows and mules spread out into a multitude of thin folia, which are placed one upon the other in a wavy or scalloped manner, like the tiles of a house, leaving numerous arched entrances beneath the flakes, so that although the insects can creep into the nest, no water can enter. Over the summit is stretched a very large flake in one unbroken sheet, like a skull-cap on a man's head, which acts as a general roof and projects on all sides beyond the circumference. The edifice tends to become spherical or balloon-shaped; its size is about that of an ordinary foot-ball. A vertical section presents an innumerable number of irregular cells, composed of the same substance as the exterior. Towards the centre they are more capacious than near the surface, and have been found to contain insects in every stage of development. These nests were discovered by Colonel Sykes in the Poona Collec-

torate, India, attached to the Kurwund shrub (*Carissa carandas*) and on the Mango tree (*Mangifera Indica*). No provision for the young appears to be laid up, and probably the house-supplies depend on daily quest. The ants are extremely small, barely one-fifth of an inch long.

The nests of another extraordinary tree ant, *Œcophylla smaragdina*, are cunningly wrought with leaves, united together with web (see Fig. 24). One was observed in New South Wales in the expedition under Captain Cook. The leaves utilised were as broad as one's hand, and were bent and glued to each other at their tips. How the insects manage to bring the leaves into the required position was never ascertained, but thousands were seen uniting their strength to hold them down, while other busy multitudes were employed within in applying the gluten that was to prevent them returning back. The observers, to satisfy themselves that the foliage was indeed incurvated and held in this form by the efforts of the ants, disturbed the builders at their work, and as soon as they were driven away the leaves sprang up, with a force much greater than it would have been deemed possible for such labourers to overcome by any combination of strength. The more compact and elegant dwelling of *Œ. virescens* is made of leaves, cut and masticated until they become a coarse pulp. Its diameter is about six inches; it is suspended among thickest foliage, and

sustained not only by the branches on which it hangs, but by the leaves, which are worked into the composition, and in many parts project from its outer wall. It may be at once distinguished from the nest of *Crematogaster* by its smoothness and regularity of surface. A species of this genus was discovered in Africa by Foxcroft, who observed that whenever the ants were molested, they rushed out of their house in such numbers that their pattering upon the papery covering deluded him into thinking rain was falling on the leaves above.

In the forests of Cayenne, the nests of *F. bispinosa* are remarkably like a sponge, or an overgrown fungus.* The down or cottony matter enveloping the seeds in the pods of the *Bombax ceiba* is used for their construction, vegetable fibres that are too short to convert into fabrics, but which the ants contrive to felt and weave into a compact and uniform mass, so dexterously that all trace of the individuality of the threads is lost. The material much resembles amadou,* and like that substance is valuable for stopping violent discharges of blood. In size the nests generally have a diameter of eight or nine inches. The ant itself is little, and dark, and noted for two long sharp spines on its thorax, one on either side; hence its scientific name of *bispinosa*, from the Latin meaning two-spined. Popularly it has been called the Fungus Ant.

CHAPTER V

SOCIAL HOMES (*continued*)

So-called humble-bees — eighteen or twenty species in this country — comparison of their habitations with the hive — Description of nest of Carder — the coping of moss — interior — dispersion of company and hybernation of females — work of latter in spring — Deep burrowers among British wild bees — Honey-bees in the East — Stingless *Meliponæ* and *Trigonæ* of South America and their homes — supposed presence of several fertile females — sentinels to guard the gates — True social wasps — their building material and disposition of combs — Particulars ot home of common English wasp — British tree-wasps — the papery envelope — Nest of hornet — Description of combs of *Polistes* and *Icarias* without cover — *Apoica* has a cover but not distinct — Card-board makers — Wasps as honey-gatherers.

LEAVING the marvellous structures of the hive out of the question, in this part of the world the only bee tribe that construct homes by the united labour of the society are the wild so-called Humble Bees. Every one is acquainted with them, big-bodied, and velvety, and heavy flyers, on the wing emitting that deep sonorous hum that has earned for them their popular title with its numerous variations. They are known not only as Humble, but as Hummel, Bumble, Dumble, Dumbledore, or Foggie, according to the dialect of the particular

locality. Though all are denominated indiscriminately by this general term, in this country in truth there are over eighteen or twenty species of these

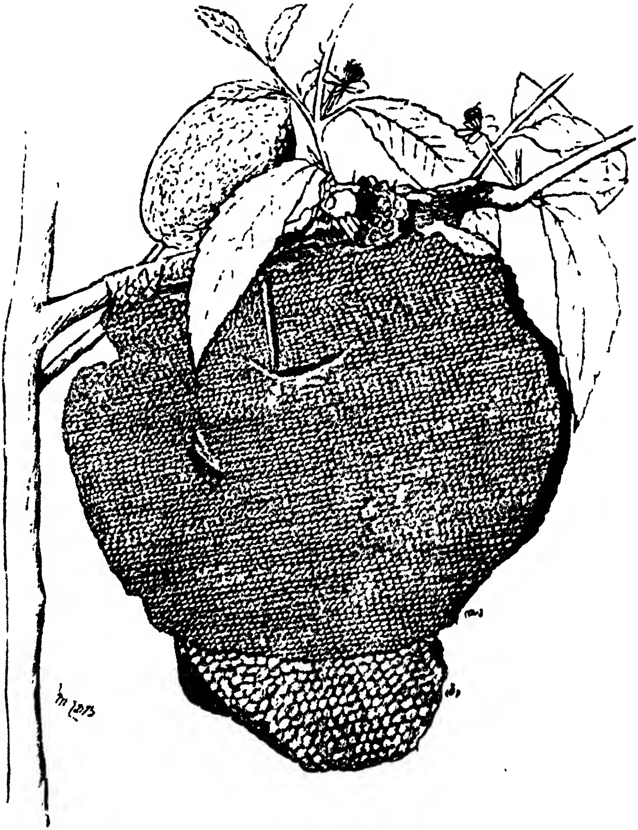

FIG. 25.—Comb of a small honey-bee (*Apis floralis*) from India. (*a*) The small cells for the workers; (*b*) The large cells for the drones.

bees, the greater part of which constitute one genus Bombus. Each differs somewhat in detail of habits, and almost interminable varieties are exhibited as regards size and colour. Yet, except in the case of some of the more prominent species, they are not easy to identify; naturally the popular mind recognises no difference; therefore no distinct common appellations have been originated for them, and unfortunately it becomes necessary to make use of the scientific names. Their habitations are rude, the number of inhabitants too is small, sometimes not more than twenty, and rarely exceeds two or three hundred. Again, contrary to the custom of the hive, there is no single female who permits no rival to divide with her the affection and deference of her subjects, and who is set apart for one exclusive function. In the Humble Bee's colonies the males, females, and neuters * so-called, dwell on terms of amicable equality together, and the females share in the ordinary duties of building and providing for the needs of the house. The males, however, as in the hive, are fewer than the workers, and idle, and when once they venture abroad seldom return.

The nest of *B. muscorum* is plentiful enough, but not easily found. Usually it is situated in open meadows and pastures, sometimes in hedge-banks where the soil is entangled with roots, at the borders of copses, or among moss-grown stones. It occupies a shallow cavity in the ground, perhaps

half a foot in diameter, either selected ready-made or formed by the bees with great labour. Over the inconsiderable hollow rises a low vaulted dome or roof to a height rarely reaching more than three or four inches above the surface, and composed generally of fragments of moss cleverly woven into an admirable covering, made to harmonise with surrounding objects with the view of concealing it from curious eyes. Besides moss, the bee's favourite material apparently — whence its name muscorum, "of the mosses," — dead leaves, grass, fern-fronds, and other matters are frequently adopted where moss is scarce or absent; but whatever the substance may be it is within easy reach, for the bee never attempts to transport anything from a distance. The material is prepared for roofing purposes in a manner similar to that of carding cotton or wool, or heckling flax. The process consists in the operator carefully disentangling the fibre, seizing it and drawing it through her jaws and forelegs, subsequently she passes it under her body by means of the remaining pair of legs, forming it as she does so into a small ball or bundle convenient for carrying home. The object of the dome is obviously to protect and hide the dwelling, which lies at the slight depth of an inch or two beneath the soil. Although the moss is laid down in considerable quantity it would be inefficient to exclude rain; and as a rule a lining is added, a thick coating of grayish-yellow wax

similar to that of which the breeding-cells are made, but of far inferior quality to the wax of the hive, rendering the interior water-tight. The entrance to the nest is in the lower part, and is generally a kind of tunnel or covered way, sometimes more than a foot long and half an inch wide, more effectually concealing the abode from observation. The occasional opening at the top seems solely for the admission of air and warmth; by it the bees are never seen to enter or depart, and it is closed at night and in bad weather.

On removing the domed coping of moss and bringing the interior into view, a different scene is presented from the delicate rows of hexagonal cells which go to form the finished workmanship of the vertical combs of the hive. In their place there are various irregular groups of oval pale-yellow bodies, arranged horizontally in a general way, the groups being more or less pressed together and connected by slight joinings of wax. These are not, as one might suppose, the work of the old proprietors of the nest, but the silken cocoons spun by the larvæ for their pupæ life, in like manner as the larvæ of other bees. Some of them, chiefly those occupying the lower combs, stand open, indicating the completed development and escape of their former inmates. Those which are closed at their upper extremity include immature pupæ not ready for their final metamorphosis. Besides these bodies, several amorphous * masses of

dark-coloured wax are perceived, of flattened globular shape and various dimensions. Opening them, a number of eggs or grubs encircled with a paste made up of pollen and honey are found. These are the true breeding-cells, formed mostly by the mother, who deposits her eggs here, and stocks the young with the supply of sweet food. The larvæ that are hatched from the eggs exhaust the store given them before they are full-grown; when it

FIG. 26 — Melipona bees gathering clay; from Bates.

is consumed the mother furnishes her little ones with daily provision until the days of their larva-hood are accomplished, and they spin cocoons for the coming helplessness of pupæ. The number of eggs or grubs contained in one spheroidal* mass varies from about three to about thirty. Intermingled with the breeding-cells and cocoons at certain times of the year, especially on the sides and in the middle of the nest, are likewise small goblet-like vessels filled with a very pure honey. They consist of cocoons deserted by the pupæ, but

it falls to the lot of the workers to refurbish the disused cells for the fresh purpose. Fragments of silk left hanging from the orifices at the emergence of the young bees they cut away, and, after shaping the rims a little, they strengthen them by rings or elevated tubes of wax, completing the renovation of each cup by the addition of an internal lining of the waxen material. The stored honey may serve to moisten the food of the larvæ, probably it also acts as nourishment to the working colony when prevented by unfavourable weather from seeking it abroad. Occasionally the bees construct receptacles or honey-pots entirely of wax.

As winter approaches these communities break up and perish, a few fertile females or queens alone surviving, the Methuselahs of their short-lived race. In utter solitude and in a state of torpor they lie in any convenient crevice; in the rotten wood of decaying trees, under moss in woods, or turf, in haystacks, in the eaves of barns and outhouses, seldom, if ever, in the nest that they have inhabited. Awaking with the sunbeams of returning spring they commence a life of unceasing labour. Diligently they search for fit spots for nest-building, or, in default of suitable cavities that would in some degree abridge their toil, each bee hollows out a small hole for herself. The moss-dome being built, she collects quantities of pollen and honey, and, when the hoarded mass is sufficient for a

beginning, proceeds therein to deposit some eggs. In a few days the larvæ are hatched, and immediately set to work to eat the food on which they are cradled. Soon they become full-fed, and spin their cocoons, and rapidly undergoing their transfor-

FIG. 27 — Home of *Vespa Norwegica.*

mations they gnaw off the tops of their cells and shortly emerge as perfect insects. Invariably the first batch of offspring are workers, who aid the queen in forming the colony. On them devolves the enlargement of the nest, and they assist in the up-bringing of their juniors in the home. Young

males and females do not appear until the season has considerably advanced.

B. lapidarius, "the red-hipped humble" of Shakespeare, one of the most abundant of British Bombi, has a preference for making its nests beneath stones. Under compulsion of untoward circumstances, it forms residences in the earth, like the common Humble Bee. The burrows of *B. terrestris* are often of great depth; no moss cover is manufactured, but the roof is lined with layers of wax. In internal construction these nests do not differ from the nest of *B. muscorum.* As a rule deep burrowers have a population twice as numerous as the more surface-building Carders. The latter are generally influenced by the weather, their numbers being much diminished by a wet unfavourable season, but, speaking generally, an autumn company seldom exceeds a hundred all told. Of all the Bombi the common Humble Bee is the most prolific, and its homes contain more individuals than those of any other species; between three and four hundred members sometimes appertain to one nest. This is a sparse society as compared with the hive; but the honey-bee is much smaller, and its cells in which it is hatched and nurtured are correspondingly minute. Those of the Humble Bee are not only large, they are set very irregularly and occupy extensive spaee. Cells capable of holding an assemblage of three or four hundred form a great group, and require a cavity to contain

them enormous in proportion to the size of the excavators. Underground-builders seem of more vindictive character than the Carders, and appear to resent interference with some ferocity. Nests of the Carders, on the other hand, may be taken almost with impunity.

The Honey Bee (*Apis*) is not wild in this country; in the East, its supposed original home, it exists in this state in great abundance. *Apis indica* and *nigrocincta*, species probably in general domesticity in India, build in hollow trees, or crevices in rocks; as opposed to *Apis dorsata*, which likes to hang its combs from the undersides of boughs of trees or rocks. *Apis dorsata* is perhaps the best known of Indian honey-bees, and is extensively cultivated in the Himalayahs. Probably rocks are its favourite natural nest-sites, where it is sheltered from the weather and the attacks of bears. In the hills, as every one knows, these quadrupeds make almost any effort to get at the combs and honey in trees, caring little for the stings of the defrauded creatures. Numbers of nests constantly hang from old buildings, such as the Taj Mehal at Agra, which is much disfigured with the pendant combs. Many attempts to remove them have been made, but no sooner is a nest destroyed than it is quickly renewed at a few feet distant. *A. floralis*, a beautiful little bee, nidifies on the branches of orange and lemon trees, and garden shrubs generally (see Fig. 25), occasionally in the interior of mud walls,

the cavities between bricks, or in holes excavated by the termites or white ants. Immense clusters of honey-combs hang in the caves of Salsette and Elephanta, in the clefts of the rocks and the recesses among the figures. So abundant are the bees, they have been known to put intrusive visitors to the rout.

From Europe, long ago, the Honey Bee (*Apis*) was imported into the West India Isles and the northern provinces of South America, where it exists at the present day domesticated, and at large in the woods and forests. Not a single species of this restricted genus is indigenous to the country. In North America the nearest ally as regards its habits is the Humble Bee, of which no fewer than forty species are known. The tropics possess considerably better substitutes in the genera *Melipona* and *Trigona*, the celebrated stingless honey-bees of South America. The *Meliponæ* have remarkably long legs, they are short and squat, generally much smaller than the hive bee, some in fact are nearly as tiny as midges, and extremely irritating for getting into the nostrils and about the head. Though they have no sting, or rather their sting is feeble and they use it seldom — whence the Spaniards call them *angelitos*, or little angels — they appear capable of biting sharply. Their colonies are often far more numerous than those of the *Apides*, and several fertile females are said to live together in harmony.

They construct homes in suitable crevices in hollow trunks, or in perpendicular banks, even in cavities of rocks by the sea-shore. The form of the habitation varies according to the species, but most kinds of *Meliponæ* are masons. It would appear that the Old World has produced far more advanced forms of animal life than the tropics of the New World, and these bees offer no exception to the rule. Their nests may be of enormous proportions, and immense quantities of pollen and honey are stored, yet their architecture is very inferior to the skill exhibited in the European hive. The *Meliponæ* are as prodigal of wax as the others are sparing of it. Their comb is composed of a single series of alveoli * applied laterally to each other, and not of two strata or layers placed end to end. Generally they are oblong, showing only here and there an approximation to the elegant hexagonal shape, and appear to be destined solely as the residences of the larvæ. The honey is stored apart from the brood-cells in great waxen vases or vesicles, with thick and strong walls. Some of these sacs have a diameter of an inch and a half, or about as large as a pigeon's egg.

The most numerous and interesting masons, *Melipona fasciculata*, are about one-third shorter than *Apis mellifica*. Little crowds of the workers are constantly employed in gathering clay, and the rapidity and precision of their movements while thus engaged are wonderful (see Fig. 26). With

the material collected they construct a wall, often in the hollow of a tree, filling up the crevice with the exception of a narrow orifice. One species, still more determined to secure safety and privacy, in addition to blocking up the gap, fashions a neat tubular gallery of clay outside its doorway; the tube has a trumpet-shaped mouth, and the particles are kneaded together with some substance of viscid consistency. At the entrance a number of the pigmy owners are always stationed, apparently acting the part of sentinels. That these bees appoint sentinels to guard their gates is a fact of frequent observation. They sedulously watch the outgoings and incomings of their fellows, and seem now and then to be relieved on duty. A relief-guard presents itself every twenty-four hours according to the Mexican cultivators, but no unreasonable doubts may be entertained of such regularity. At all times the sentinel-bee occupies the hole leading to the interior, and as often as a worker desires to enter or to quit the nest, momentarily withdraws within a small cavity on the side of the aperture, resuming its station with surprising alacrity whenever the individual has passed in or out. In Jamaica, where probably the species are similar, if not identical with those of Mexico and the Brazils, no fewer than three sentinels have been seen opposing the entry of the black ants that infest forest trees. The assistants stood behind their principal, heads downwards, and, clinging to

the upper arch of the entrance, they gazed upwards, steadily scanning several ants within the crevices of the bark, prepared to rush in if the guards remitted their vigilance for one moment. The active ants paced upwards and downwards in lines, eager for the booty, but were allowed no greater satisfaction than a rapid reconnoitring of the doorway.[1]

Bees of the genus *Trigona* hang their combs outside on the branches of trees, at the very summit of the tree and the end of the slenderest twig, so as to be out of the reach of the monkeys. In shape the nests are like a large pear, and, judging by the dimensions of some and the multitudes inhabiting them, it seems hardly possible to doubt that they contain several prolific females, as in the *Meliponæ*. While the *Meliponæ* are chiefly, or exclusively, restricted to the warm regions of the New World, the *Trigonæ* extend into India, Africa, Australasia, and to the Isles of the Eastern Archipelago. The honey of some species is sweet and altogether excellent, that of others is black and sour and quite worthless, but dark honey, as of *Trigona ruficornis*, may be well flavoured. The wax, too, is sometimes very dark and unctuous,* though susceptible of being whitened somewhat by bleaching.

The hives for domesticating the *Meliponæ* in Mexico are primitive, and follow closely the habitat of the bee in a state of nature, being

[1] *Naturalist's Sojourn in Jamaica.* Gosse.

simply a portion of a hollow log of between two and three feet long; a hole is bored into the interior through the sides midway down the length, and the ends are stopped with clay. They are usually suspended on trees in a horizontal position, and are quickly taken possession of by bees. While some of the combs are vertical, others are situated horizontally, the cells of the latter being the most numerous; all are ranged together at some distance from the opening. Externally to these are the clusters of sacs for the honey, affixed to the wood of the cavity by processes of wax, or to each other, and frequently placed side by side; the disposition of a group as a whole has some resemblance to a bunch of grapes. Taking advantage of the irregular position of the sacs, the cultivators abstract the honey by removing the clay

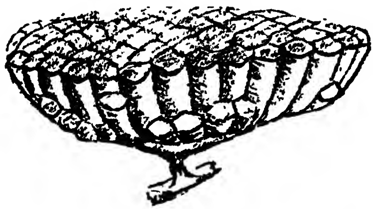

FIG. 28.—Comb of *Polistes tepidus*, Fabr., with centre pedicle; from Saussure.

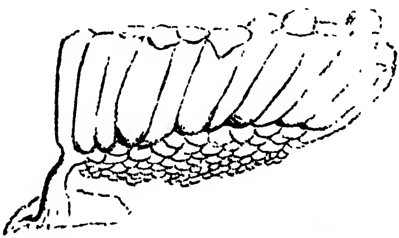

FIG. 29.—Comb of *Polistes canadensis*, Linn., inverted, with lateral support and irregular cells, many still containing nymphs; from Saussure.

plug from the bottom of the hive, and secure the riches without injuring, almost without disturbing, the inmates. The end is again closed, and the bees, robbed of their treasure, lay in a fresh store.

The true social Wasps, which are arranged in one large family, the *Vespidæ*, form communities whose architectural labours will not suffer on comparison even with those of the inhabitants of the bee-hive. In fact, for daintiness and delicacy the nests of many of the *Vespidæ* constitute the most beautiful examples of insect architecture. As with the bees, the great object of their industry is the safety and upbringing of their beloved young, and in like manner they construct combs for their reception, consisting nearly always of hexagonal cells. The building material they employ, however, is totally dissimilar to wax, and the plan of their city differs from that of the hive. These nests show many discrepancies, and their situations vary; but though they are heterogeneous in detail, in the essential and most important points they are all alike.

The common English Wasp (*Vespa vulgaris*) is a handsome insect, much disliked for its fondness for everything sweet and its formidable weapon of defence. The gardener especially holds it in abhorrence, on account of its depredations on fine ripe fruit. Still it is more a predaceous than a vegetable feeder, and the evil it commits in respect of the peaches, and so on, is perhaps more than

counterbalanced by its good works in ridding us of many a tiresome fly and similar pest. Usually situated in a cavity underground, the nest is a marvel of ingenious industry. Of more or less globular shape, and about sixteen to eighteen inches long by twelve or thirteen broad, it is inclosed in a coating of material some half an inch thick, like coarse brown paper, though not so tough, made up of numerous thin leaves or laminæ, which do not touch but have small intervals between them, and is evidently intended to prevent the earth from getting among the combs inside. If this external portion is removed the combs are exposed, generally from twelve to fifteen in number, circular, and of different sizes, and disposed horizontally in distinct and parallel tiers one above the other. Each consists of an assemblage or layer of cells of papery stuff like the covering, their mouths directed downwards, so that their upper ends or bases, which are slightly convex, together constitute an almost level floor, on which the wasps conveniently pass to and fro in attendance on the young hanging in the comb of cells immediately above. These terraces are supported by fixture to the sides of the nest, and each is attached to the preceding one by cylindrical columns or pillars, of a compact paper. Access from tier to tier is gained by openings between the walls of the combs. At the bottom of the nest two main holes exist, the entrance and exit ways

common to the community. A covered road leads from the surface to the subterranean dwelling, often a long and tortuous path, an approach carefully concealed though well known to the miners.

This wonderful structure arises from a small beginning. In the early spring a solitary wasp or two may be observed here and there, flying neither high nor fast, but plainly on a tour of inspection of the earth-banks, scrutinising into the opportunities they offer for the formation of a home. These are females who have just awakened from their hybernation. At last the wasp meets with a crevice to her mind, the abandoned burrow of a field-mouse maybe, or of a mole, or perhaps the forsaken tunnel of some large burrowing insect. She examines it in every particular, she fusses in and out, she appears to deliberate; eventually she assumes proprietorship, and prepares to enter into possession. The first thing to be done is to form a chamber to her liking at some distance below the surface; so she breaks away the soil, and carries or pushes it out bit by bit. The cavity being ready, the next item of procedure is to lay the foundations of the house to be included, which contrary to the usual custom of builders is begun at the top. Taking leave of the home-site for a time, she flies off to a wooden post, or rail, a window-frame, or some such thing, where with her jaws she busily gnaws [illegible] the fibres until she

amasses a little bundle. She kneads, and triturates, and moistens the filament with saliva, re-

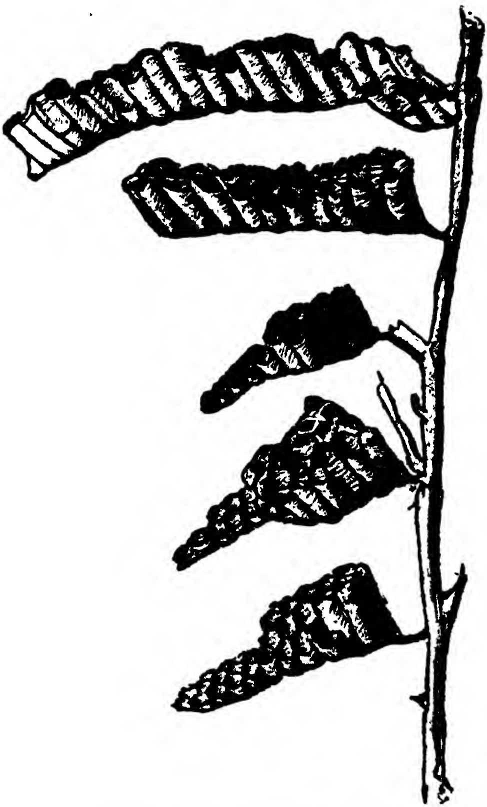

FIG. 80.—Nest of *Icaria variegata*.

ducing it to a homogeneous paste or pulp, a kind of *papier-mâché*. Back to the nest she hurries

with her burden. Here the ductile mass is made to adhere to the centre of the ceiling of the chamber by her jaws and forefeet; meanwhile she clings to the ceiling by her two last pairs of legs. Supply after supply is acquired and placed, until a pillar about half an inch long, pendant from the ceiling, is complete. At the extremity of the pillar, with the same material and in like manner, she attaches three very shallow cylindrical cup-like cells, in depth about a tenth of an inch. They hang bell-wise, and in each she deposits an egg. The young things require protection, and over them the mother simultaneously constructs a roof, umbrella-shaped, and made of paper as the cells, but laid differently, the length of the fibres being almost at right angles to the middle of the proposed comb. On either side of the first group cells are added close together on the horizontal floor, eggs are laid in them, and in correspondence with the enlargement the roof is extended. The covering is of considerably rougher texture than the cells, and no attempt is made to smooth the surface.

By this time the three eggs that were first laid are hatched, and the larvæ have to be fed; they increase in size, and their cradles must needs be bigger. The poor mother finds plenty to do,—she has to construct cells, to lay eggs, to enlarge the cell-walls, and to seek for food wherewith to satisfy her more advanced offspring. Soon, however,

the worst of her troubles are over. The first-born become full-grown, cease to feed, and inclose themselves within their cells, each in its own white silky cocoon with convex cap, and shortly emerge as perfect insects. The work now goes merrily on, for these young wasps are workers, who take upon themselves the arduous share of the labours of the hive. They increase its extent, and become nurses to their younger companions, while the mother does little but lay eggs in cells as fast as they are made. As time goes on, brood after brood of recruits is added to the army of workers, new cells rise quickly, and are as quickly supplied by the mother, and before long the first cell-terrace is completely filled.

Various pendant pillars, similar to the foundation pillar, now appear on the underside of the comb at the angles where these cells meet. To their extremities cells are caused to adhere, and by dint of additions they soon all unite and form a second terrace below the first, the distance between the two tiers being about half an inch, or equal to the height of the intervening columns. A third, a fourth, and a fifth tier are constructed, and the roof or walls of the building are constantly brought down lower. The cells composing the foundation terraces are amongst the smallest in the completed nest; they are too small to admit the head of the female, who when she gives the inmates nourishment feeds them entirely from the outside. It

follows that the wasps bred in them must be of less size than the mother, they are indeed all undeveloped females or workers. The cells of the next few tiers are much larger, being the breeding-places of the males and females. Thus, then, workers only are brought forth early in the season; the males are hatched subsequently, and the virgin females latest of all. The terraces gradually increase in diameter up to the fourth or fifth, when they usually decrease slightly, and in exact conformity with this formation the covering is constructed. They are not perfectly perpendicular but somewhat raised at the corners, so as to form a trifling concavity in the centres of the floors. Though the cells are cup-shaped at their bases, they become beautifully hexagonal as they rise in height, or rather in depth, particularly at the middle of the combs; a large nest contains from about 7,000 to 10,000. Each is believed to be the birthplace of three generations, with the exception of those intended for the males and females which are probably the cradles of but one brood. Wood fibres seem a flimsy substance of which to make such an edifice, and by which to sustain so great a multitude, but as a fact the walls are very strong, and the hexagonal shape of the cells affords mutual support.

Scarce is the building finished ere it begins to show signs of dissolution. The summer is over, the several broods of workers have passed through

the cells, and the single generation of males and females have become mature. The males are dead, the workers likewise desert the home and die, and the majority of the females, a few only seeking refuge in cracks and holes, where they survive the winter, and live to be queens and founders of fu-

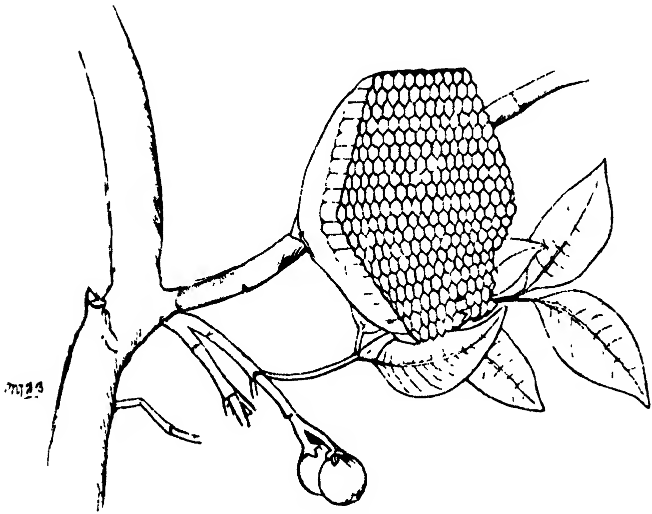

FIG. 31.—Nest of Brazilian Wasp (*Apoica pallida*).

ture colonies. Out of a vespiary holding three hundred females in the autumn, barely ten or twelve will see the spring. Before deserting the cells should any grubs remain undeveloped, the workers, apparently prescient of their coming doom and aware that there will be none to discharge the duties they must themselves lay down, carry forth

the helpless nurselings and forsake them, — arrant cruelty on the face of it, in reality an act of mercy, substituting a quick death by exposure, or by falling a prey to some creature's appetite, for the slow lingering death by starvation that would be theirs were they left neglected within the nest.

Occasionally *V. vulgaris* dispenses with a burrow, and builds from beams in the corners of outhouses; under a thatched roof is also a favourite locality.

Among the British Tree Wasps, which habitually make pensile nests, the best known is *Vespa Britannica*. In the South and West of England it is rare, but is plentiful in Scotland. Its lovely globe-like dwellings it boldly suspends from the extremities of branches of trees and shrubs, chiefly the fir and the gooseberry. *V. sylvestris* has a wider distribution, but is scarcely so common, and is a burrower at times. The outer shell or envelope of the pensile nest, very fine and choice in relation to the covering of the subterranean combs of the common wasp, is made of a smooth and white-gray paper, its individual flakes being sharply defined. It is impervious to water, and protects the combs admirably, to which however it is never attached. The opening is at the lowest part, and underneath, and is sufficiently large to give free entrance and exit. For beauty, delicacy, and utility, the Tree Wasp's nest is unrivalled (see Fig. 27).

As the population of a wasp community increases

and the cells must be augmented, laborious is the undertaking, since it necessitates that the inner sheets of the covering be cut away to make room for the greater size of the comb, or combs, while faster than these are removed additional layers are formed externally, to maintain, and even to slightly add to, the thickness of the walls. Thus is the human architect careful to proportion the thickness and consequently the strength of his walls, to the magnitude of the building about to be erected. This method of enlargement of the nest-cover obtains among the species *sylvestris*, *Norwegica*, and *rufa*. In the case of the subterranean dwellers, *vulgaris* and *Germanica*, and among the hornets, the mode consists not in the superposition of layers, hollow pieces of material are formed, blisters, as it were, are raised all over the plain outer surface as left by the queen when she renounced her architectural labours. Blister after blister is placed one above the other, and, as in the former instance, the underlying matter is cut away nearly as quickly as the fresh formation is added. The material removed is not discarded as useless, but worked up afresh; as a fact, this is performed by the act of removal. Subsequently it serves both for new cells and for additions to the outside. The alteration of a subterranean dwelling involves the greatest toil, for besides the changes necessary in the envelope plainly the area of the nest-cavity must be enlarged. Care is always taken to keep

free a clear, though tiny, space between the papery shell and the earth interior.

The fabrication of the papery sheets that together make up the powerful envelope is a perfect work of art. One is astonished at their resemblance to our own gray paper. This paper is simply thinner, more silky, more smooth and glossy; it offers great analogy to papers made by island savages from the bark of trees. When a wasp bears a fibrous ball of paste to the nest, and adds it to that piece of the covering on which the builders are engaged, it draws out the little mass with its jaws and feet into ribbon-like form along the edge of the wall, reducing it to the requisite thinness much as a mass of metal is pressed by the cylinders of the rolling-mill. During the operation the wasp invariably walks backwards. The tongue then adds the finishing touches, giving the paper a brightness and polish. A colony labour simultaneously, and the workers bring their morsels to the same point of the nest, resulting in a regular transverse zone. Every nest shows these zones of formation of the paper, sometimes not very distinct because they vary simply from darker to lighter tones of gray; but often the stripes are quite pronounced and of different colours. The wasps go forth solitarily in search of building material no doubt, and must bring in stuffs of various sorts. But when one finds a good working-stock, others seem to become cognisant of the fact and hasten to the spot, and

the zone constructed will be of a particular colour. If, for example, a birch be the object attacked, the zone will be white; if a poplar, the zone will be green. The same wasp, however, it has been observed, does not always bring in a load of the like colour. But she seems sensible enough not to deposit her lump behind material different from her own, she puts it against similar substance, and mixed bands are never made.

The separate sheets or leaves of paper are not complete sacs, shutting in the combs as an egg is inclosed in its shell. They are limited in size and imbricate * with one another, and are kept in place and are in contact together merely at the points of imbrication. Flat cell-like spaces occur between them, except towards the summit of the nest where the envelope forms a thickish compact mass. The points of fusion of two successive layers never fall precisely the one above the other. By this mode of construction each layer of paper lies on a stratum of air, a disposition that withstands inclemency of weather. The whole of the exterior layers may be soaked with rain without soiling in the slightest the leaves beneath. The paper of *Vespa*, though sticky, is not varnished, and wets easily. But it will dry in the sun, and not be in the least deteriorated.

The nest of the Hornet (*V. Crabro*), tolerably plentiful in many parts of England, is identical in character with that of the wasp. It is larger than

the wasp's nest and the cells are larger; its paper is rougher, and the columns that support the comb-tiers are higher and more massive, the central one especially, which is about twice as thick as any of the others. This insect does not favour the underground for a dwelling; it lodges in out-of-the-way corners in thatch or under the eaves of barns and out-houses, and is extremely partial to save itself trouble by building within old tree-trunks hollow from decay. The cavity need not be particularly large when it is adopted, for the hornet is liberally provided with the means of excavation in its sharp and powerful jaws. A nest so situated has no definite papyraceous envelope, the hornets seem to understand perfectly that the wood with which the combs are surrounded affords sufficient protection in itself, and they provide coverings only for those parts that are more or less exposed. Thus the entrance hole is always obstructed by leaves of paper which close it as much as possible without impeding the way out. Under other circumstances hornets are at great pains to shelter their combs within a papery coating of many thicknesses, an envelope that constitutes an excellent example of the appearance produced by obtaining strength of walls and large dimensions of comb-tiers by constant exterior additions of puffed-out papery cells. They open on the surface of the nest, where they are very regular, by narrow entrances, always directed downwards, the object being doubtless to

prevent any substance falling from above from penetrating inside. Saussure believes the use of these entrances is to permit the access and circulation of air amid the vacuities of the envelope, for the purpose of drying the papery leaves each time that they are wetted and softened at the surface. The real entrance to the nest is at the inferior extremity, as in other *Vespæ* that nidify in the open atmosphere.

When hornets take up domicile within a hollow trunk they frequently seem to make no use of the large hole of the tree, but go to the trouble of digging a gallery through some undecayed portion. It assumes a winding direction, and probably protects the nest from intrusion. In the opinion of Reaumur, hornets can distinguish a rotten tree, to all appearances healthy. They bore through the sound wood to reach the interior, and gnaw the cavity to suit their convenience. This penetration of the living matter is difficult, and the hole is never enlarged beyond the limits necessary to admit of free locomotion in and out. The materials removed in excavation go to form the cells, and the coverings, what coverings there be. Some of the nests are of great size, even three feet long, and wonderfully fragile, due to the choice of rotten wood for the manufacture; whereas other wasps scrape their vegetable fibres from moist living sources, and make a firm and tenacious structure. The hornet's paper is very friable, and

excessively yellowish or russet-coloured, widely different from the silvery-gray composition for instance of *Vespa Norwegica.* In a sense the hornet is more indefatigable than the wasp. At night the wasp retires within doors for sleep, but if the moon be up, the hornet steadily pursues her tasks; even when the moon deserts her, she is prone to do night-work.

Leaving *Vespa* we pass to the *Polistes*, a group of wasps with elongated bodies and the first segment of their abdomen* drawn out into a long pedicle. This genus is essentially exotic, though it occurs sparingly in England. Their system of nidification, while inferior to *Vespa*, far exceeds that of the latter in diversity of plan. The nests differ in shape, and are very variable as much for size as for mode of attachment, but the combs are always destitute of any covering envelope; the young, however, are perfectly safe inside. The position of the nests is not purely horizontal, but oblique* or vertical, so that they are adapted to casting off the rain. If, on the contrary, the cells faced upwards they would fill with water; were they directed downwards the water must lie on their basis as on a flat roof, and in course of time must sink through. The insects take the further precaution of turning them towards the north or north-east, because during the summer and autumn in these climates the strong cold winds, and those that bring rain, usually come from the opposite

quarter. Their impermeability is increased by a varnish, probably a glutinous liquor, secreted by the wasps, which is well rubbed on to the papery surfaces.

Though each species seems to have a form of nest which it favours, still one hard and fast line is by no means adhered to; seemingly the *Polistes* approve of the maxim that circumstances alter cases. Many of the dwellings are circular or approach the round (see Fig. 28), some are as though compressed, some oval, some simply composed of one or two long lines of cells, some are eccentric, forming at first a triangle which is finished with a rounded end. The solid foundation of the comb and the strong slender pedicle * that maintains it may be central; in other cases it projects entirely from one side of the support (see Fig. 29). The nests never reach a great size, often there is only one tier; additional combs are attached by pillars or foot-stalks as in *Vespa*. The cells are roundish, and remarkable in that their bases are a trifle smaller than their mouths, a divergence hardly noticeable in the single cell, but which produces a spreading outline when a number are massed together. Those in the middle are large and long, and generally closed, indicating that the larvæ are within, undergoing their transformations to perfect insects. As a rule the peripheral cavities are much shorter, open and empty, indeed one would imagine them to be abortive,

and too small to be of any use. These are mere rudiments or outlines, and originate in a thrifty habit of the wasps of constructing not only cells that they wish to fill, but of preparing others to come in handy by-and-bye. Within the little cups, the bottoms of future cells, eggs can be laid, and later on the walls can be lengthened. These sketches, several deep, sometimes form a ring round the great cells, or comb properly so called. They are of advantage in permitting of rapid additions to the nest, in a sense they insure its well-being by lessening the bad effects of any shock or blow, and they alone would be flooded in the event of penetrating rains. They are less well proportioned than the mediate cells, even the form of the nest as a whole indicates that they are the most oblique, the most divergent, and difficult to construct. Probably to this cause must be attributed the variety to which the nests of all kinds of *Polistes* are subject. There seems reason to believe that the individuals bred in the lateral apartments are neither so large nor so perfect as their kindred fortunate enough to enter the world in the more beauteous central cradles.

Polistes aterrima forms its cells with beautiful regularity and sets them in a very peculiar manner, two deep on the same horizontal floor, and in a couple of pendant rows. They open downwards, but are not quite perpendicular, they incline a little alternately to either side. Each is placed

rather lower than its fellow, producing a striking general effect and one easily recognisable. Slight and perishable as they appear, the rain may fall in torrents without wetting them. Over the whole the wasp lays a thick coating of a blackish but transparent varnish, which renders them waterproof; it also binds the group firmly together, and gives it a high polish. The small dimensions of the nest lead one to think that these wasps form societies of a different nature from those of immensely populous communities. Towards its basal end the cells become small, a diminution that arises simply from the fact that they are yet incomplete; originally the upper cells were in the same unfinished state. It is incorrect, though very natural, to suppose that the higher and larger compartments are for the future males and females, the lower and smaller ones for the breeding of the workers. The similarity of completed cells raises important questions. Are these societies true societies, do the males and females belong to the same brood, are they of like size, and nurtured in the same cells? Possibly the sexes are reared in separate establishments, on the principle of unisexual or diœcious * plants.

Not the least extraordinary of the wasps are the *Icarias*, a genus that extends through most of the warmer regions of the world, specimens having been taken in Africa, India, China and Australia, and in many parts of the Asiatic Archipelago.

Like the *Polistes*, their nests are attached to leaves, stalks, or branches by a single foot-stalk, composed of the same papery material as the cells. Though slender it is hard, tough and solid, and the strength with which it is fastened to the tree or plant is surprising, enabling it to uphold considerable weight. At the end of the petiole usually a single cell, its mouth directed downwards, is fixed; the rest of the nest consists of a double series of lateral cells until the group is complete. Those nearest to the foot-stalk are the largest and most perfect, since they are finished first; towards the other extremity the cells gradually diminish in size, and at that point they are only just begun. As a whole they are well-defined hexagons, their colour is often a rather dark yellowish brown, preventing them from being conspicuous in spite of their curious projection. The cell-masses are small, so that the societies must be restricted. Possibly each group is the work of a single female, who confines herself to raising her own progeny which escape as soon as they are hatched. The nests are frequently numerous in the same spot, and each society may set up a number of separate homes in the vicinity of one another. Perhaps in this genus, as among the *Polistes*, workers are wanting (see Fig. 30).

The architecture of *Apoïca* may be compared with that of *Polistes*. If one were to impaste a great canopy-like mass of cellular matter to the

dorsal face of a circular cell-group of *Polistes*, then one would have a nest of *Apoïca*. The comb opens downwards, its upper surface is con-

FIG. 82.—Wasp's Nest (*Chartergus apicalis*), interior and exterior.

vex, not that the cells group themselves in a cluster round a central point, a mode often giving birth to convexity of surface, the canopy or ceiling is itself hemispherical, and to its inferior face the

group is attached. The cells are of about equal length, thus the thickness of the nest is almost the same throughout, and the under surface is generally more or less concave, so that the edges of the sphere project and afford a certain amount of protection to the middle portion. The cellular canopy is a spongy substance, not unlike a lather of soap; in reality it is a species of paper, and when torn or cut offers some resemblance to cotton-wool. It is usually of a yellowish or tawny * colour, and somewhat gummy and glossy. This paper is kneaded and worked up by the manufacturers until it becomes uniform, and shows no trace of the successive sweeps of the insects' jaws, so plainly exhibited in the papery coverings of the English wasps. The thick hemispherical cap is varnished on the exterior, rendering it weatherproof; its use is clearly to protect the bed of cells against rain and any body that might strike them in falling from above; in fact it takes the place of a roof to a house. It likewise envelopes the branch, or branches, to which it fixes the nest, its sticky nature being here of great importance, and serves to bind the comb firmly to the plants. The cells are sometimes nearly circular, or deviate faintly from that form; some of them are perfect hexagons. It is a most remarkable fact that in the same way though the entire nest-mass at times is round, or diverges little therefrom, often it too is hexagonal, and its six sides are as regular and the

angles are as true as if they had been drawn with rule and compass (see Fig. 31). This is commonly the case with the larger nests;—the great ones reach a diameter of eleven or twelve inches. But near combs of the kind may be found quite small hexagonal specimens, showing that the insects have started with the idea of constructing on these lines, and having begun thus have adhered to the conception.

The wasps hitherto considered are distinguished as manufacturers of paper, in general fine and thin and more or less brittle, the weakness of which they overcome by the superposition of a great number of leaves. There is a large class who while they make many kinds of papyraceous tissues, are noted for a feature in common—the fabrication of a solid and tough paper, a veritable cardboard, composed of only one layer of material, at times very thick and resisting, at others slight and supple. Of this substance, after the manner of *Vespa*, the wasps usually build a papyraceous envelope or sac for the inclosure of their combs, and as in that genus,* the covering follows closely the direction of the plan of the cells. These nests attain an extraordinary degree of development and house a vast multitude of individuals; even our nests of *Vespa*, the best suited of the previous category to support large populations, are extremely limited compared with some of the societies in question. The cause of the excessive

increase is unknown, whether it be that these societies are formed on other bases, or that the climates that give them birth do not impose such stringent periodic destruction upon them as our winter season does upon those at home. Exposure to the more favourable climatic conditions, however, does not lead to great increment among *Vespa* and *Polistes;* many of these companies abroad can hardly be said to be less scanty than ours, and it seems not unreasonable to conclude that a distinct difference lies at the root of the economy of the two classes.

The genus *Chartergus*, one of the important groups of the cardboard-makers, includes insects apparently similar which practise two strangely different forms of nidification. The nests of *C. chartarius*, the most common in collections, are of frequent occurrence in tropical America. Their cardboard is white, gray, or of a buff colour, tending to yellow, very fine and of polished smoothness; at the same time it is strong and so solid as to be impervious to the weather. It cannot be urged sufficiently, says Reaumur, that this kind of envelope is indeed of a veritable cardboard, as beautiful as any we know how to make. Reaumur once showed a piece to a cardboard manufacturer, and not the slightest suspicion of its real nature was suggested to his mind. He turned it over and over, he examined it thoroughly by the touch, he tore it, and after all declared it to be made by one of his own

profession, mentioning manufacturers at Orleans as the probable producers. The nests may be conical or cylindrical, they may be straight, but more often are somewhat curved, some are almost globe-shaped, but these varieties are of little importance. The length of a well-sized nest is about a foot; the largest yet discovered was in Ceylon, and measured the astonishing size of six feet. The edifice is pendulous on trees, and attached as it were to a suspensory ring, which embraces the branch, and is tightly impasted round it, or according to Westwood may be large compared with the latter's circumference, but it is probably a mistake to say that the nest ever swings freely as on a pivot. The interior consists of circular concave horizontal platforms of cells, their mouths turned downwards, each tier stretching right across like so many floors, and fastened along its entire edge to the walls. Communication is effected by a central opening through the bottom, and through every tier. When the number of inhabitants becomes very great and a fresh series of cells is added, unlike the British wasps who add to their abodes by a preliminary increase of the envelope to admit of extension of the tiers, the *Chartergus* go to work on precisely the opposite plan, first forming new cells and covering them afterwards. Taking the bottom of the nest as starting-point they set cells over its exterior surface, being careful to extend the circumference by a row or two to augment the

diameter in proportion to the length, so that the symmetry of the building may not be lost. The walls are then lengthened to include the fresh stage, and the end is closed with a new floor, in its turn to become the ceiling of the next tier of cells when further enlargement is desired. No trace of the addition is visible on the outside of the envelope, which would seem constructed at one stroke.

The nest of *C. apicalis* is uneclipsed for grace of design; it is one of the most wonderful examples of intelligent workmanship among insects. Exteriorly the form is a more or less fusiform * or spindle-shaped sac, terminating at its inferior extremity in a prolongation or narrow neck, which is open and constitutes the entrance. The sac surrounds and impastes the branches of trees, which piercing it almost from end to end act as its support. To the branches, in the interior a number of combs, one above the other much as in *Vespa*, are affixed; as a rule the largest and straightest among them becomes the axis to the whole edifice. When the axes are multiplied, the regularity of disposition of the combs is destroyed; numerous small cell-groups are commenced on the different branches, and at different levels, and do not unite to form perfect and complete tiers. Due to the shape of the spindle, the higher and lower combs are the smallest, the least mature, so to speak; the middle ones are given ample room in the inclosure, and

may be increased to great size. While the former are simply fixed against the axis and are more or less spreading, the larger tiers tend to surround it on all sides, so that the axis penetrates through them, though always somewhat eccentrically. Communication between the terraces is by spaces on the inner side of the covering, a simple sheet of paper, which, though slight, is solid and well gummed. Its surface is irregularly indented; sometimes wrinkled transversely and circularly, and with great exactness. In some nests, on one or other of the faces, the points where the zones of paper and the wrinkles meet are very plainly shown, making the spindle look as though it were goffered. The branch that is accounted the true axis is never vertical; a slanting one is chosen as affording greater support. The neck projects to one side, and consequently it becomes necessary if the combs are to retain a horizontal position, that they cut the stem at an oblique angle.

Notwithstanding the sustaining power of the axis, the tiers stand greatly in need of certain accessory though irregular props. Frequently they are united by pedicels, or columns, and are affixed to the interior of the covering by their edges by little scales or sheets of paper, leaving holes to enable the wasps to get from story to story. In this manner they are kept in their place, and the covering itself is rendered stronger by its numerous points of union with other substances. Another

important means of support is gained by arched strips of paper adherent to the envelope, and more or less perpendicular to it, which traverse the inner space and unite the borders of the combs, forming as it were vertical partitions upon the interior circumference of the sac. Enlargement of the nest is effected as in *Vespa*, but with greater difficulty, since the envelope is composed of a single leaf. Great cell-like papery protuberances are raised on its surface, and subsequently the portions covered are eaten away by the builders from the inside. The pedicels, or columns, above mentioned, which unite the combs to each other, arise from careful preservation of parts of the old mantle, which naturally extend from the border of comb to comb. In the same way the vertical sheets of paper alluded to, which bind the combs to the new portion of the envelope, originate in the retention of the old leaf throughout its lines of meeting with the fresh superimposed coat; and when the combs are extended to reach that coat, the strips form the partitions described upon the circumference of the tiers, adding much to their solidity. In spite of all these clever precautions the nest, owing to the feeble character of the envelope, is one of extreme fragility.

The other kind of nest of *Chartergus* is constructed on a straight and upright branch, having no lateral twigs. Its elegance cannot be sufficiently admired. Composed of a few cells only, the combs

are attached to the branch by means of petioles, or solid masses of wax, keeping the groups in a horizontal and parallel position. They stand one over the other, sometimes to the number of ten, separated by considerable intervals, and so admirably upheld by the petioles that the aid of all pillars or columns is dispensed with. The envelope is a spindle of a single leaf of ligneous* paper, most artistic in appearance, being marked with transverse parallel tubings and goffered. The fibres of the tissue are arranged with surprising regularity; all the zones are united with consummate art, and meet in a long and plainly shown line; the paper may be also variegated with longitudinal bands of different colours. The vase is firmly affixed to its axis at points slightly above and below the uppermost and lowermost combs, at no part is it in continuity with the combs, there is plenty of space between the two fabrics for the wasps to pass up and down within their home with ease. Taking advantage of the wholly lateral* position of the combs with respect to the axis, the wasps render their building less fragile than it would otherwise have been by placing the branch to one side of the spindle, and it saves time and trouble, without materially impairing the support, to leave the wood exposed at the posterior surface of the papery mass. The opening is small and situated at the lower end (see Fig. 32).

The pensile nest of *Tatua morio* bears great exter-

nal resemblance to the pendulous cone-shaped nest of *Chartergus chartarius*, and is common in the same country. Two remarkably good specimens may be seen in our national collection. The outer walls are of a solid and durable paper, which is likewise thick, hard, smooth, and of a dark brown. Storms, however fierce, have little ill-effect on homes so well protected. Hardly less thick and strong are the various cell-floors, like the floors of the *Chartergus* circular in plan, but flat, and the union of each with the envelope is absolutely perfect. The entrance, however, is entirely lateral, and the insects gain admission to the different tiers by very eccentric* holes. A nest well in progress contains many combs. In one of the kind the lower chambers are likely to be incomplete, since the floors are made before the cells are built. The wasps seem always to be in readiness for an emergency; they build new stages ere they require them, and lay the foundations of future cells. The construction of the former is a long and toilsome business, but the latter are quickly formed, and eggs can be laid in cells that are just begun; during the development of the larvæ there is abundance of time to finish them. How many tiers are made before cells are attached to them, or whether cells are added as soon as the floors are completed are at present moot points. Though at the beginning of winter the nests are abandoned, they long resist the severity of the season; whether the societies are dissolved

every year has not been ascertained. It is equally uncertain if colonies take possession of deserted nests or invariably build anew. Each comb may serve for one laying, or may be cleansed and put to further use.

The genus *Polybia* is common in tropical America, in the Asiatic Archipelago it occurs more sparingly but is unknown in Europe. Some of the small homes, as those of *P. palmarum* and *sedula*, generally consist of a single comb of hexagonal cells on the surface of a leaf, and clothed with a ceiling of somewhat frail paper, with an aperture towards the lower end. The insects have the sagacity to fix them to the underside of the leaf, so as to cause it to bend and form a natural roof. The building is also made to follow the shape of the supporting foliage, being round or oval under large broad leaves, long and slender under linear * leaves, and its size is always carefully limited, so that the leaf projects on all sides. When the comb is full it appears that a second stage may be added upon the cover, and is completed with an envelope or ceiling. The regularity and perfection of construction is wonderful.

P. liliacea makes a marvellous and often gigantic nest, four to five feet long, and of a diameter of one or two feet, containing thousands of cells. It is suspended from the branches of trees ; its covering is a rough cardboard, sometimes of a red-brown ; it is compressed at the top but widens out towards

the base. *P. rejecta* ofttimes forms a cone-shaped pendant nest, which when increased to great extent ends in a long symmetrical cylinder. Other

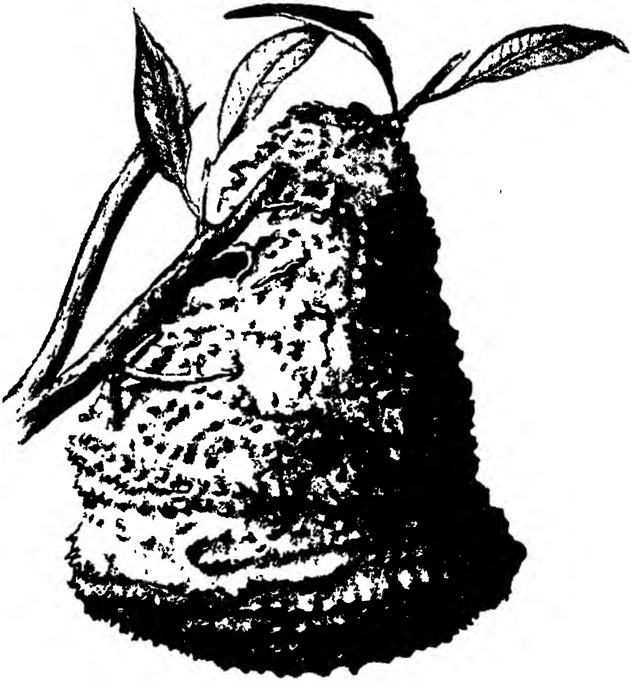

FIG. 83.—View of exterior of nest of *Myrapetra scutellaris*.

nests are flask-shaped, the base being fastened to the tree; some are almost globular. The species to whom the last belong, carrying out still farther the principle of enlargement adopted by *Charter-*

gus chartarius and *Tatua*, build by placing cells not merely upon the outer surface of the layer of cardboard which at the moment constitutes the

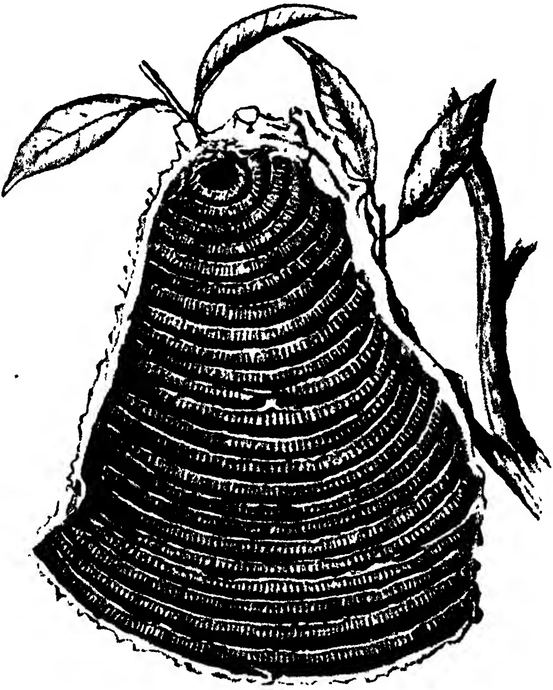

FIG. 84.—View of interior of nest of *Myrapetra scutellaris*.

bottom of the nest, the entire outer wall is covered with cells, when the fresh tier is closed in with a new envelope. Thus a fairly large nest is composed of a whole series of concentric combs, form-

ing hollow spheres set one within the other, not unlike the well-known ivory puzzle balls of the Chinese, the papery ceiling of each comb having been originally the outer wall of the nest. It follows from this arrangement that the direction of the cells is not uniform, as is generally the case with social Hymenoptera. They are neither all placed vertically with their mouths downwards, like those of most wasps, nor are they horizontal, as made by the bee. On the contrary, their bases all point towards the centre of the nest, and all their mouths radiate outwards. The various comb-tiers are generally remarkably close, and pierced with holes for communication.

Very extraordinary are some of the nests belonging to this genus in the collection of the British Museum — the works of *Myrapetra scutellaris* (see Fig. 33), a mere fanciful title. These huge erections are from Central America, and the native authorities say of one that it is not composed of wood fibres, but of the dung of the Capincha, one of the aquatic cavies of the region. One's attention is instantly attracted to the fairly conical knobs or tubercles * with which the surface is thickly beset, of various size, and most pointed where they are least exposed. Their disposition is in horizontal zones, seeming to correspond more or less with the comb-tiers. While at the top of the nest they are comparatively few, gradually the numbers increase towards the lower end, and on the bottom they are

so numerous that one's finger can scarcely be laid between them. Like the envelope they are made up of several papery layers so closely blended as to be hardly distinguishable, forming a substance astonishingly thick, hard, and firm, in colour of a dull dark brown, and of very coarse texture. Of what use they are it is difficult to decide; they may be simply freaks of nature. Although their tips are not acute, they may defend the abode against the attacks of tigers, jaguars, kuguars, and other mammalia partial to honey and the grubs of the hive. The nest always hangs low, seldom more than three or four feet from the ground, and protection would appear much needed. It seems hardly possible to deny that they are for the double purpose of concealing and of sheltering the entrances, which are invisible when the nest is looked at from above. Examination reveals them beneath a row of the projections, which overhang them and keep off the rains like the eaves of a house; the passages are also intricately twisted, so as to prevent the ingress of moths or other enemies of any size. It is strange that the inferior surface of the nest is provided with tubercles, a circumstance that must put the insects to the trouble of gnawing them away each time they add a stage. Probably the same material is again employed in establishing fresh cells, and in building the new platform.

A longitudinal section shows the peculiar dispo-

sition of the combs. Just as in the spherical nests of *Polybia*, the highest ones are perfect, or almost perfect, spheres; but this method of construction is soon found to be too laborious. A nearly globular mass of the brown paper-like substance exists at the top, the nucleus so to speak. The first combs closely surround this, so that they form the best parts of hollow spheres, then come great arcs of circles, followed in regular order by other tiers, their rotundity becoming gradually reduced until the curve of the lower ones is extremely shallow, exactly like the tiers of *Tatua*, except that they exhibit a trifling convexity on their lower surfaces. They are carried to the common wall, and thereto affixed, small spaces being left open here and there between their edges and the envelope. The solid wall at the top is of great thickness (see Fig. 34).

In the nest in the British Museum already described, a quantity of brownish-red honey was found in the upper combs, but hard and dry. Even so long ago as the beginning of the century, Azara, a Spanish officer, who was sent out by his government to Paraguay to make certain investigations in that country, mentions that a South American wasp which he calls Chiguana has the strange habit of hoarding honey. The Chiguana of Azara, it would seem, is identical with *Polybia scutellaris*. At the time of publication Azara's statement was not believed, so opposed was the habit that he claimed for this insect to the known

actions of wasps. He and his men ate from the Chiguana's store, and it proved deleterious. St. Hilaire, a subsequent traveller, speaks of two South American honey-wasps. The honey of one was white and innocuous, that of the other was reddish-brown and poisonous. The good honey was in an oval light-coloured nest, of thin papery material, totally different from the paper of *Myrapetra*, and was observed by Hilaire on a small bush near Uruguay, at a distance of only about a foot from the ground. This wasp has been described as Lecheguana. Probably under the term Lecheguana, or Chiguana as Azara has it, the inhabitants of America confound many wasps of similar kinds, and it is rather a generic title for all honey-wasps than for one species in particular.

That honey is contained in these nests there can be no question; the fact is proved beyond doubt by those in the British Museum. At the same time it is evident that the papery material is extremely ill-suited for the retention of the liquid, which has penetrated and dropped from layer to layer of comb and materially damaged the cells. A nest of *P. scutellaris* containing honey was presented to the Museum about thirty years ago. In no part of it were brood, nor did it appear to have been recently in use for the purpose of hatching. Can it be possible that it was a deserted nest, adopted by a society of wasps merely as a temporary receptacle, a magazine for booty? Wasps are

well known to plunder hives, and the honey may have been treasure stolen from the stores of some *Melipona* or *Trigona* bee. If *Polybia* are really makers of honey, it seems only reasonable to expect that their cells would be of a nature to contain it; moreover, that the stock laid by would constitute food for the young as well as for the community at large. It must be admitted that the absence of brood may be explained by the supposition that the collection is made in the off-breeding season, when the company would consist solely of adults; and when the death or repose of natural life precludes the wasps from gathering food abroad, the honey would serve them in good stead. The idea has been started, but merits little credence, that a nest of this kind is a forsaken wasps' nest invaded by some species of *Trigona* bee. Wasps' cells are unadapted to the great pursuit of bees, besides being considerábly too large for the proper accommodation of these bees' larvæ.

The *Nectarinia* are likewise believed to be collectors of honey. Their beautiful globular nests, of fine gray paper like the paper of *Vespa*, but made up of a single layer, are plentiful in the deep recesses of the Brazilian and Mexican forests, being suspended near the ground from the boughs of bushes, while long delicate leaves and branches are woven into their substance, and in many places are carried through it and project on the other side. As in the case of *Myrapetra*, they consist of

series of tiers composed alternately of comb and cover, the last being the leafy envelope. The spheres are more perfect than those of *Myrapetra*, but they are not always literally concentric* circles, and in reality they are incomplete towards the summit of the nest. This irregularity is unavoidable, for if the combs were only united at the top they could not be kept fixed firmly in their relative positions; no pillars of union between them exist, as in *Vespa*. Nature substitutes an excellent contrivance, which is at once a means of communication and a prop to the edifice. A veritable flight of stairs extends throughout the nest from the centre to the lower surface. The *Nectarines*, like other cardboard wasps, pierce holes through their successive stages as a means of traffic; the combs being of immense breadth, the holes are numerous to save time and fatigue in gaining the exits, and the overcrowding of the passages that would otherwise result in the populous communities. But these routes are not deemed adequate for comfort and convenience. To the underside of the great orifice with which each comb-tier is perforated, material is added, and prolonged obliquely downwards, so as to meet the platform of the comb lower. Tier after tier, from the top to the bottom of the nest, bears the same arrangement; the hole in each tier is situated below that of its immediate predecessor. It will be perceived that the wasps in descending or ascending by these

stairs and through these holes, pass in spiral* fashion from the centre to the circumference of the nest. The envelope itself is penetrated with a hole, and the ladder leads out into the open air. These communicating sheets have other uses. Determined to make the most of everything, the industrious wasps cover the undersides of the papery plates with cells. They are therefore comb-ceilings, as well as staircases and pillars. Without going into details, the domain may be said to be enlarged by an extra sphere of cells upon the outside of the envelope and a fresh coat of paper.

If the outer surface of a nest were covered with cells it would hold some thousands. Since the interior is made up of numerous similar surfaces, little smaller, one can hardly compute the sum total of inhabitants possible to be contained in such a city. Of all the kinds of wasps' nests, this of the *Nectarines* is the best for holding a large community. Due to its sphericity, the cells find room with the least expenditure of material. And while it can exceed others in cell capacity, and consequently in population, in actual volume it is far less cumbersome than other great nests.

CHAPTER VI

DEFENCES OF INSECTS, OR PROTECTION AS DERIVED FROM COLOUR

Need of insects of means of defence — Adaptation of their external colouring to conditions of life — Protective Resemblances — herein find explanation of first and most widespread use of colour among animals — Principle of adaptive colouring solved by theory of natural selection — Commonness of general harmony between colouring of insects and tints of nature — Imitative tints of undersides of wings of butterflies — Special Protective Resemblance — "stick-caterpillars" and others — leaf-butterflies — British and European moths — among Orthoptera — tropical "walking-leaf" and "walking-stick" insects — other insects and spiders — Alluring colouring — Resemblance of Mantises and spiders to flowers — to excreta of birds — Changes of colour corresponding to changes of environment — Di- and Polymorphism — their value — meaning obscure —Variable Protective Resemblance in pupæ — in larvæ — in colours of cocoons — in perfect insects —Variable Protective Resemblance and the origin of colour — Power of adjustment of colour is adaptive, and is produced and maintained by natural selection.

It is unnecessary to enlarge upon an insect's need of means of defence. Obviously no creature could be more open to attack, and added to its peculiarly defenceless condition on all hands innumerable enemies wage continual war, many of whom derive their whole sustenance from insects.

Nor are these tribes at peace with their own kind, but ever live in a state of internecine broil, the strong often preying on the weak and the cunning upon those of simpler wit. An insect is like a country of diminutive size, and apparently almost wanting in natural safeguards. No seas of unrivalled swiftness of motion roll round it and shield it from the depredations of foes; no mountain barriers of strength enable it to withstand them. But our insect world is not without resource. Though small, its inhabitants are in multitude infinite; and though from their nature seldom able to flee or to fight, on them are bestowed different modes of resistance to fate to save the race from extirpation.

Among biological phenomena of great interest, the principle of disguise has long been known to exist in most classes of the animal kingdom. In other, perhaps plainer, words, their external colouring is adapted to their conditions of life. The resemblances are of different kinds; the most usual are cases of simple concealment. The animal in form as in colour imitates or simulates, more or less exactly, the appearance of some object in its environment which is of no interest to its enemies, and thus passes undetected; or it harmonises in a general way with its surroundings, and so succeeds in eluding attention. In these instances the object imitated is invariably inanimate or part of a vegetable structure. The

analogies go by the name of "protective resemblances."

It does not seem possible for an insect to be more simply and admirably defended than by this system. More or less complete, concealment is useful to many animals, but to insects it is absolutely essential, and accordingly in insects adaptation to environment is most fully and markedly developed. In the animal world the members eat as they are eaten. To those that live upon others, and to whom activity and energy are denied, compensation in the boon of colour is also important —colour such as may best serve the possessor to avoid alarming its prey, either by its presence or its approach. That in this explanation is learned what is the first and most widespread use of colour among animals seems corroborated by the fact, that protective resemblance is apparently possessed by insects in proportion to their sluggish movements or absence of other means of defence.

This principle of adaptive colouring, though early recognised, found no intelligible exposition until the year 1859, when it met with perfect satisfying solution in Darwin's theory of natural selection, by which he explains how it was that evolution took place. Formerly among a certain section of the community the problem was referred to an originally created specific peculiarity, or the adaptation was understood to be due to the direct action of climate, food, or soil. But while the former in-

terpretation puts an effectual bar to reasonable inquiry, since we cannot get beyond the fact of the adaptation, the second was found to be far from adequate to cope with all the varied phases of this strange phenomenon, and was controverted by some well-known facts. The gradually increasing change of disguised species, from a general harmony with surroundings to precise imitation of particular objects, is rather to be accounted for by the laws of a struggle for existence and survival of the fittest, while the elements permitting the birth and progress of the resemblance exist in the individual variability of the species, a variability that is hereditary.

The commonness of the occurrence of a general resemblance or harmony of colouring between insects and the prevailing tints of nature, a similarity in general artistic effect, is hardly conceived by those unaccustomed to watch or speculate upon such things as these. In the different tribes, in the most adverse orders, this kind of protection abounds, affording its several possessors greater or less degree of invisibility to the prying eyes of antagonists, or the fear-fraught glance of the wished-for prey.

In the tropics the colours of thousands of species, though perhaps brilliant and far from being alike, blend completely with the aspect of the spots where the insects habitually repose. At a few feet distant the surface and the insect may be

absolutely indistinguishable. It is one thing to see an insect by itself in a collector's cabinet, quite another matter to witness it in the state in which

FIG. 35.—A "Stick-caterpillar" (*Ennomos tiliaria*), which in colour, form, and attitude closely resembles a twig of a tree upon which it lives.

it ordinarily exists. Seen apart from its surroundings it may appear bright, and not adapted to escape observation; in its everyday haunts, probably, that

very brilliancy enhances its concealment. The truth is we fail adequately to appreciate the tones of inanimate nature. We make little or no allowance for the infinite complications wrought by the ceaselessly changing play of light and shade upon colours which in themselves are far from uniform. A gaudy insect with numerous hues, if viewed in connection with its surroundings, or at a distance, may match neighbouring objects, and be lost as it were, or at least may obtrude itself less than if uni-coloured, or adorned with tints more feebly contrasted. For this reason many tropical insects that take diurnal rest clinging to the bark of dead or fallen trees are not wholly brown; the brown is delicately mottled with gray, the disposition of the two colours being symmetrical and in endless variety of design. Nearer home, to take a familiar example, the large and common caterpillar of the Privet Hawk Moth (*Sphinx ligustri*) is in reality striking in its green dress and purple stripes. But although it looks so conspicuous it harmonises remarkably well with its food-plant, and is sometimes troublesome to find. The purple, a dangerous introduction of colour one might be led to suppose, tends to neutralise the vivid effect of the extensive green area.

However, deception of assailants or assistance in capture is often obtained by the reproduction with great exactness of the colour of the soil, or the vegetation inhabited by the insects. Of this mode

of defence the beetle family offers no dearth of illustration. Among Cicindela, *C. campestris* frequents grassy slopes and is green; *C. maritima* is found only on sandy shores by the sea, and is of a pale brownish yellow. Dr. Wallace discovered many of these insects in the Malay Isles invariably in harmony with their place of abode. *C. gloriosa*, of a velvety-green, was always taken on wet mossy stones in the bed of some mountain stream, the brown *C. heros* chiefly on dead leaves in the forest paths. The wet mud of salt marshes alone furnished a glossy-olive species, so closely corresponding to the colour of the mud that it was only distinguished, when the sun shone, by its shadow! Where the beach was coralline and nearly white, Wallace saw a pale Cicindela; where it became volcanic and black, a dark species of the same genus presented itself. A small weevil mercilessly persecuted by ground-beetles abounds in pits of a loamy soil, of the same colour precisely with itself, undoubtedly facilitating the escape of many from their foe. A scarce British weevil, by its gray colour spotted with black, is an equally good counterpart of the locality where it generally seems to roam, which consists of white sand mixed with black earth.

In some cases a species confine themselves entirely to one species of tree, whose bark they simulate in colour and rugosity. They are excessively abundant, and surely it cannot be considered ex-

aggerated to regard the protection derived from the resemblance as a factor, and no small one, in the flourishing condition of the race.

Numbers of our weevils and other beetles when alarmed drop off the leaves on which they are sitting, at the same time rolling themselves into little lumps or balls. It is useless to look for them on the ground, where they lie motionless amid stones and earth-pellets, the appearance of which they simulate exactly.

The fact is well known that however gay the upper surfaces of the wings of butterflies may be, the undersides are nearly always sober, often very dull and obscure, and in some instances have been observed to be like the surfaces whereon the insects customarily rest. This arrangement of colour is eminently protective, because during prolonged repose a butterfly takes care to hold its wings raised perpendicularly over the back, effectually to conceal its lovely but treacherous possession. Moths usually have their chief colour on the hind wings, the fore ones are dowdy and often imitative in tint, and generally cover the lower pair when the insects are not in flight. Probably a thorough examination of the habits of our butterflies would reveal their under surfaces to be much more frequently imitative than at present we believe to be the case. The concealment afforded by this means is effective, judging by the total disappearance of common butterflies in bad weather. While some

take shelter by creeping into nooks and corners among thick-set leaves, others cling freely exposed to surfaces that blend harmoniously with their own tints.

To pass on to the more specialised forms of protective resemblance, not confined to colour, but

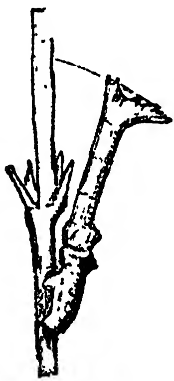

FIG. 36.—The caterpillar of Early Thorn Moth (*Selenia illunaria*), showing supporting thread of silk; from Trans. Entom. Soc.

FIG. 37.—Appearance of the larva of Brimstone Moth (*Rumia cratægata*) when seated among the twigs of its commonest food-plant; from Trans. Entom. Soc.

which extend to outline and shape, and deal with the attitudes of the insects. As combining all these several features, no better instance could be found than that offered by the caterpillars of the Geometræ moths, "stick-caterpillars," or surveyors, or loopers, as they are popularly called. For hours together these larvæ will sit motionless, projecting at an angle more or less acute from the bushes on

which they feed looking for all the world like the plant's own branches. The caterpillar is long, slender, and cylindrical, it holds itself stiff and immovable, so as to hide as far as may be the separations of the segments, and its free end where it terminates in the head one imagines to be the bud at the end of a twig. Little humps or tubercles likewise frequently exhibited on the body pass readily for additional buds or irregularities of the bark, and tend greatly to increase the resemblance. The likeness is promoted by the peculiar disposition of the legs. While the majority of larvæ have five pairs of claspers, or legs persistent only in the caterpillar state, Geometræ possess but two pairs attached to their anal extremity. With them the caterpillar firmly grasps the stem, rendering them very inconspicuous, and to preclude the appearance of any limbs, the pairs of true legs immediately behind the head in many cases are applied closely to the body. The twig-like attitude is abandoned solely for feeding, which as a rule takes place in the evening or at night (see Fig. 35).

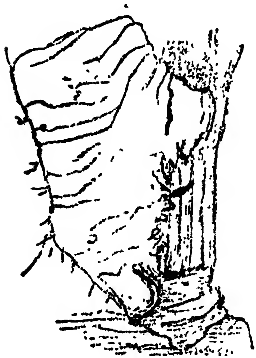

FIG. 38.—The hind part of the larva of Brimstone Moth (*Rumia cratægata*), seen from the right, showing the claspers and the fleshy projections which tend to fill up the furrow between the larva and the stem; from Trans. Entom. Soc.

On the face of it, this posture seems one impossible to be borne. No creature fashioned horizontally with the surface would be capable of erecting itself at an acute angle with its support, and of continuing to keep the position for any lengthened period. Unaided, the caterpillar does not make the attempt. Fatigue is obviated by spinning a thread of silk, which is fastened at one end to the stem, the other end remains attached to the head of the insect (see Fig. 36). That there is considerable tension upon the brace may be seen by cutting it, when the larva falls back with a sudden jerk. In some cases the caterpillar is enabled to endure the strain by holding a leaf or twig with one of its pairs of articulated* legs.

Many points of detail concur to promote this deception of Geometræ. The head is modified from its normal shape into one extremely suggestive of the top of a twig, or some vegetable growth, or at least to convey no hint of its real caterpillar nature. Commonly it is notched, a plan forming a very natural end to the apparent twig. In the caterpillar of the Small Emerald Moth the segment behind the head is humped as well, while the latter is retracted, so that four blunt projections are produced, carrying out yet more admirably the resemblance to a twig. Similar unevennesses are obtained by the head and first body-rings being bent backwards (see Fig. 36). It might be supposed that the claspers by which the stem is held

would excite attention and betray the insects. They however partially surround the branch, and appear to grow out of it (see Figs. 37 and 38). Lest the intervening space between the front and hind pairs should reveal the fraud, the underside of the larva is somewhat flattened, so that it lies in contact with a small portion of the round stem. On either hand the furrow is decreased, in some species at any rate, by the presence of fleshy protuberances (see Fig. 38). The colour of the larvæ is usually obscure, in general agreement with that of the bark of a tree; sometimes the various tints of a stem are reproduced with marvellous fidelity. The Geometræ are a widespread and numerous tribe, divided into an immense number of species — there are between two and three hundred in this country alone, a result that has been brought about, doubtless, by their acquisition of a form and attitude so well suited for purposes of concealment, admitting of their success in life's race, to the detriment of larvæ with less perfected methods. In their wanderings Geometræ have come to feed upon a variety of food plants. These changes have in some cases necessitated corresponding modifications of attitude, of colour, or of form, in order to bring the larvæ into harmony with their environments.

Caterpillars of other groups secure protection by the imitation of surrounding vegetative objects, though perhaps hardly to such an astonishing de-

gree. Some resemble the bark of thick branches, and repose against the bark, closely adhering to it.

FIG. 89.—Leaf-Butterfly in flight and in repose; from Wallace.

The furrow that they would make with the branch is obliterated by hairs, or by a row of fleshy projections, at least in all probability this is the use of these structures. The appearance of lichens* is also commonly simulated by larvæ that ordinarily rest on lichen-covered bark. "Stick-caterpillars" in the earlier portion of their career do not stand upon the branches, but upon the leaves of the plant on which they feed, where the twig-like attitude would be inappropriate. Some are green in colour, so that they correspond with the leaves; in other cases the caterpillars are brown, as at later times, and the attitude is then often modified to avoid danger. Twisting itself into spiral or zigzag shape, the insect passes muster as a bit of dead and curled up leaf, or as the excreta of birds or snails. Imitation of the excrement of birds is however rare and exceptional.

In mature Lepidoptera, the most wonderful and undoubted case of the higher form of protective resemblance is that of the Malayan Leaf-butterfly, *Kallima paralekta*, and its Indian ally *K. inachis*. The method of concealment has been described by Dr. Wallace, who was the first to observe it, in his *Malay Archipelago*, and elsewhere. The upper surfaces of the wings are showy, conspicuous, and large, with a broad rich orange band across the fore-wings on a deep bluish ground. Opposed to this brilliancy the under surfaces, though varying greatly, in every case are of sombre tint, of some

shade of gray, or brown, or ochre, such as is common among dead or withered leaves. 'Mid leaves of the kind on a nearly upright twig the butterfly rests, and in this position with the wings tightly closed over the back, thus exhibiting their under surfaces, is in exact agreement with its surroundings, the irregular outline of the folded wings forming a direct and finished representation of a moderate sized leaf, shrivelled or withered in some stage of decay. The tip of the fore-wing is produced into a point, a common form of leaves in the tropics; the hind-wings terminate in a short narrow tail, which touches the branch, and typifies a perfect leaf-stalk. From end to end along the whole length of the supposed leaf runs a distinct dark line, the seeming mid-rib; from this on either side radiate oblique lines imitative of a leaf's lateral venation.* The butterfly disposes of the rest of its body so as to bear out the deception. In place of keeping its head and antennæ in motion, a custom with butterflies, *Kallima* does not expose these parts, and draws them back out of sight between the bases of the wings. The middle pair of legs by which the insect clings to the branch, and keeps the "leaf" in due position, are slender and almost invisible among the twigs and fibres that surround it (see Fig. 39).

Dead or withered leaves are often attacked in different places by various kinds of minute fungi, and are pierced with holes by insect larvæ. In

conformity with their patterns, extraordinary to say, the undersides of the wings of the butterflies exhibit representations of blotches and mildew. In many cases they are irregularly covered with patches and spots, so closely resembling fungi found on dead leaves that it is almost impossible to believe the creatures in truth are not suffering from incursions of real fungi. Their semblance of a larva's hole is equally accurate and telling. The scales covering the wings are absent from a window-like naked spot on each fore-wing, which is therefore only clothed with the thin transparent wing membrane. When the butterfly raises its wings in the position of rest these spots come together, producing the effect of a hole, since the two membranes are almost of the transparency of glass.

Colour, form, size, and habits have thus each their parts to play in this marvellous resemblance, and that it affords protection is shown by the abundance of individuals that possess it. To the habits of the butterfly is assigned not the least important *rôle*. Of what avail would be the disguise were the insect prone to settle upon a flower, or green leaf, or other inappropriate surface, or to open its wings and display its attractive colouration? The Malayan species seems to be as wary during the brief pauses between the flights as during lengthened rest. Dr. Wallace has observed scores of *K. paralekta* in Sumatra, where they fre-

quent dry woods and thickets, and they were never seen to settle but on bushes or trees with dry or dead leaves. They settled, and, as if by magic, were lost. Search for them on these occasions was usually in vain, for while gazing intently at the

FIG 40.—A "Walking-Leaf" Insect; from Belt.

very spot where one had disappeared it would suddenly dart out, and again vanish a few yards farther on. But the butterfly has been detected reposing, and its close assimilation with the surrounding leaves was then evident. The flight of *Kallima* is swift, a circumstance affording great as-

sistance to the fraud. In a recent paper, Mr. S. B. J. Skertchly calls attention to the fact that leaf-mimickers of several genera—and *Kallima* among them—settle in a totally different manner from that of other butterflies. The latter when about to alight gradually slacken speed, but the leaf-butterflies "fly rapidly along, as if late for an appointment, suddenly pitch, close their wings, and become leaves."

Keen observation would probably bring to light many cases of special protective resemblance among our British and European moths. Such as *Agriopis aprilina*, *Acronycta psi*, and many others which remain by day on the sides of trunks of trees so exactly resemble the gray and green lichens that cover the bark as to be distinguished with difficulty. *Bryophila* and many Geometers are the very images of the mortar walls or the surfaces of stones that they frequent. Numerous gray and white Geometers which rest on the upper sides of leaves forcibly suggest the excreta of birds. The well-known Buff-tip Moth (*Pygæra bucephala*) is admirably disguised by resembling a broken end of a decayed and lichen-covered branch, the cylinder-like effect being obtained by the wings being carried round the body. The Lappet Moth is also very perfectly concealed by resembling an arid brown leaf, both in shape and colour. As seen in flight, the Yellow Underwing (*Triphæna pronuba*) might likewise be mistaken for a withering leaf

tossed along by the wind. The Herald Moth (*Gonoptera libatrix*), one of the most beautiful of these imitations, represents a red-brown leaf having succumbed to a certain amount of white fungoid growth. Lest its bright eyes * should expose the deception, a tuft of hair falls over them and conceals them during rest. The delicate veil is easily raised as the insect takes to flight.

It has been remarked that a striking harmony exists between the colours of the British autumn

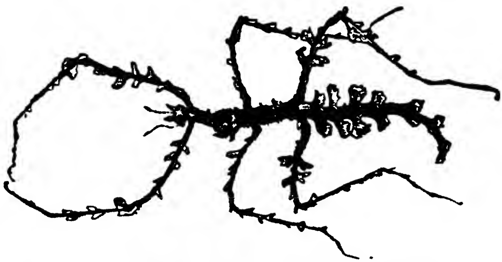

FIG. 41.—A "Walking-Stick," or Moss Insect; from Belt.

and winter moths and those that prevail in the respective seasons. In autumn vegetation as a whole dons a sober brown and yellow livery, and out of fifty-two species then on the wing, forty-two are of corresponding shades. Gray and silver are the characteristic tones of nature's winter garb, and accordingly these tints predominate in the winter moths.

The Lepidoptera apart, the whole order of Orthoptera (grasshoppers, locusts, crickets, &c.)

will be found to be signally happy in respect of the possession of this protection, every grade in

FIG. 42.—Imitation of a Flower by a Mantis (*Hymenopus bicornis*) in active pupa stage; after Wallace.

resemblance being represented, from a general harmony with the vegetation or soil commonly surrounding them up to the most striking examples of special imitation of definite objects. Many of the tropical Locustidæ and Phasmidæ, in the colour, texture, and veining of their elytra, are like green leaves; others represent leaves in various states of decay. In none the dissimulation is carried to greater extent than in the wonderful genus *Phyllium*, "the walking-leaf" (see Fig. 40). Not only have the wings assumed the appearance of leaves, the thorax and legs have been equally adaptive, and have become flat, expanded and leaf-like, to the elimination of their ordinary forms. When the insect is resting among its food-plant often the closest scrutiny fails to distinguish the difference between the animal and the vegetable. Many of the species of Phasmidæ — the family to which this insect belongs, the "spectres" or "praying insects" as they are popularly called — are known as "walking-sticks," from their singular resemblance to twigs and branches. Their colouring, form, rugosity, and arrangement of the head and legs are all in accurate accord with the appearance of dead sticks; in a word, when "walking-sticks" are seen stationary it seems scarcely credible that an imposture is being played. In Brazil, and elsewhere, some are no less than eight inches and even a foot long and of the thickness of one's finger. They hang about shrubs in forests,

and have the extraordinary habit of holding out their limbs unsymmetrically, the better to typify a branch with lateral spray (see Fig. 41).

In a case recorded by Dr. Wallace the trickery does not end here. A "walking-stick" (*Ceroxylus laceratus*) obtained in Borneo exactly resembles a stick grown over by a creeping moss or jungermannia,* an appearance due to certain foliaceous excrescences or irregularities, of a clear olive-green colour. So absolutely identical were the counterfeit and the reality, the native Dyak who brought in the insect maintained it was grown over with moss, although alive, and it was only after minute examination that Dr. Wallace could convince himself that the fact was not so. The change of character is pronounced. In Darwin's opinion there is nothing improbable in this insect having varied in the irregularities on its surface, and in these having become green.

Importance is attached to the details of form and colour in the Beetle family. The small Buprestidæ, for example, which generally rest on the mid-ribs of leaves, closely resemble the excrement of birds. *Chlamys pilula* is undistinguishable from the dung of caterpillars. The genus *Chlamys* furnishes another illustration of this method of concealment and protection in a brilliant and beautiful beetle, said to suggest some kinds of fruit by the inequalities of its red-coloured surface. Some of the Cassidæ, from their shape and colour, sparkle

like dew-drops upon leaves. From the Heteroptera we get a representation of a withered and crumpled leaf, with the edges turned up and eaten away, as if by caterpillars. Some bugs simulate leaves in skeleton, when the parenchymatous * portion has disappeared and the network alone is left. Spiders are often protectively coloured, and imitate the lichen on tree-trunks (as *Philodromus*). They are eagerly sought by insectivorous * animals, so that the resemblance is doubtless to their immense advantage. In many cases, however, their adaptation is chiefly aggressive, enabling the spiders to capture their prey.

Turning to Aggressive Resemblances, certain carnivorous insects, as the *Mantidæ*, are well concealed by harmonising with their surroundings. This, though to a large extent protective, also assists them to creep upon, or to lie in wait for, their prey. Aggressive Resemblance becomes of more than ordinary interest when it not only screens an insect from its prey, when it simulates some object pleasing or attractive to the latter, and so induces its approach — it acts as a lure, and entices the unsuspecting victim into the spot for convenient capture, into the very jaws of death. Species of mantis, both from India and Africa, are endowed with this dangerous fascination. They have all the appearance of fine flowers, things of special value to insects of vegetarian tastes. They draw

near, and of course are greedily made away with by the seeming blossoms.

Hymenopus bicornis, a mantis of great rarity, inhabiting India and Java, in active pupa is an inimitable representation of a flower. Colour, form, and attitude all conspire to produce the remarkable deception (see Fig. 42). These mantises may be white or pink. The thighs of the four posterior legs are expanded into broad pear-shaped plates, constituting the apparent petals, and when the species is seated they are spread out two on each side, while the fore-legs are tucked out of sight under the thorax. There need be not the slightest hesitation in stating that even butterflies are attracted, as insects to flowers, and the deceivers feed on the dupes allured. An equally interesting instance of this striking simulation is exhibited by another Indian mantis, *Gongylus gongylodes* (Linn.). It is, however, only the under surface of the animal that displays the resemblance. The leaf-like prothoracic * expansion, instead of being green, is of a clear, pale lavender-violet colour, inclining to mauve, and acquiring a reddish tinge towards the margins, and with a black-brown blotch in the centre, representing the opening of a tube in the middle of a flower's corolla. The insect is addicted to hanging head downwards amongst a mass of green foliage, and remains motionless, or occasionally sways about like a flower touched by a gentle breeze. With its fore-limbs banded violet

and black, and drawn up in the centre of the corolla, it looks exactly like a papilionaceous * flower. The disguised limbs act as a decoy to insects, which fly directly into the sabre-like raptorial * arms of the simulator.[1]

The resemblances of spiders to flowers are probably chiefly cases of the same offensive disguise, as opposed to purely defensive imitations. The bunches of blossom of the way-faring tree, *Viburnum*,* have been observed to be occupied by spiders of a pale creamy white, the exact tint of the flowers, and their abdomen closely resembled the unopened buds — of which there were many in each cyme — not only in colour, but in size and shape. These spiders are by nature hunters and not web-spinners, and the number and variety of insects that visited the blossoms were great. Somewhat later in the year similar, if not identical, kinds were seen on the wild guelder-rose, and on *Orchis maculata*. Many bushes of the mealy *Viburnum* were growing close by, but their blossoms were over. The spider on the guelder-rose had reddish-brown spots on the side of the abdomen, but not sufficiently distinct to interfere with the perfection of the disguise. But in the case of the one on *Orchis maculata* the spots on the sides of its abdomen were large, of a dark red-brown colour, and very sharply defined; and when he stood in his usual position, with his head downwards, they very clearly resem-

[1] *Proc. Entom. Soc.*, 1877, xlix.

bled in size, shape, relative position, and—at a yard's distance—even in colour the dark purple pollinia * of the flowers. Though many of these spiders were present on *Orchis maculata*, not a single one could be discovered on the dwarf orchis (*O. ustulata*), which is much like *maculata*, but its pollinia are not dark. Mr. Nottidge suggests that as the season advances these spiders change colour, and each successive change specially adapts them for concealment on the blossom of some special plant.[1] Mr. Jenner Weir[2] has also seen these spiders (*Thomisus citreus*) station themselves in the centre of a composite * flower, with their legs expanded like its exterior rays, and sometimes in the flowers of orchids, with their legs expanded horizontally. Apparently they are capable of destroying even the honey-bee, which he has found dead in their clutches.

Beautiful examples of Alluring Colouring occur in the resemblance of Mantidæ to the excreta of birds. Flies are often attracted by such droppings, and the Mantidæ take advantage of this fact to secure their prey. A similar instance was discovered by Mr. Forbes in Java, in a spider (*Ornithoscatoides decipiens*), whose imitation of a bird's dropping from a height on a leaf is carried out with minute detail—colouring, form, and habits contributing to the success of the resemblance see (Fig. 43). This is one of the most remarkable instances of faithful

[1] *Proc. Entom. Soc.*, 1878, xl., xli. [2] *Loc. cit.*

assimilation of an animal to a vegetative or inanimate object, and affords a wonderful example of what is in the power of natural selection to accomplish. The principle of natural selection alone is sufficient to explain the case, for the acquisition of every new grade in the likeness would at once give the owner an advantage in the continual struggle for food.

In the foregoing cases of protective resemblance the imitated objects are constant in their nature, and the disguising characters of the imitating species remain constant throughout the lifetime of each individual. As regards leaf-butterflies and others which resemble withered leaves, the constancy of the individual is no less perfect, but the imitated objects vary slightly in hues, calling forth a corresponding variability of colour among the copying species. There are a few examples where each insect undergoes a rapid change of colour *once* during its lifetime. It acquires a new habit, entailing change of environment, and with the fresh surroundings relationship must be set up. Obviously this change of habit in the species is equivalent to a change of character in the imitated object. Among insects in this class may be mentioned the larva of *Sphinx ligustri*. When full-fed previous to pupation, it deserts its food-plant and descends to the ground to find a suitable burying-place, where its bright green coat would be conspicuous and rife with danger. Accordingly the caterpillars

lose their original colour, and become brown, bringing them into consonance with their new surroundings. Professor Meldola was the first to perceive the true meaning of this change. An instance is afforded by Geometræ of exactly the opposite alteration at a corresponding period. In its young days the larva (*Ennomos angularia*) is a brown "stick-caterpillar," and receives special protection from its resemblance to twigs. Eventually it forms a cocoon of green leaves loosely put together, so that its body is plainly visible through the leafy screen. But at the same time its brown colour disappears, and its surface becomes green, due to its green blood, which is visible through the transparent skin.

The tendency in caterpillars is to become dull in colour on the approach of pupation, and these incidental changes, in all probability, have constituted the accidental resemblance to the soil, the initial start as it were, from which the definite alteration has been developed by natural selection.* That the change must sometimes prove disastrous to the individual is unquestionable. If at this crisis of life a caterpillar of the Privet Hawk Moth were to descend upon turf, or ground covered with other green vegetation, it would still turn brown, although its green dress would conceal it more effectively. But assuredly on the whole the change must be advantageous to the species, else variations conducing to it would not have

been preserved, but would have been neglected, and finally lost. In caterpillars closely allied to *Sphinx ligustri*, which feed near damp, green soil, the assumption of brown is far less marked.

These alterations in colour naturally suggest other differences of appearance known as di- or polymorphism. The larvæ of certain insects regularly appear under two conspicuously distinct

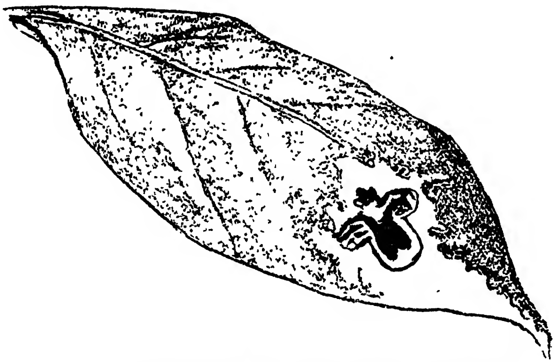

FIG. 43.—A Bird's Excreta mimicking Spider; from Forbes.

forms, chiefly a green and a brown. The circumstance is altogether apart from sex, and seems to exert no influence upon the future perfect insects. Dimorphism is also present in perfect insects, in the Lepidoptera especially in the females. It occurs likewise among male spiders. As regards ants and others of the social Hymenoptera, the individual differences of the females are most pronounced. Here, however, the mean-

ing is obvious since each form is set apart for different labour, an arrangement advantageous to the society, and consequently to the species. The benefits that accrue from larval dimorphism are difficult to determine, but we may depend upon it that advantages to the species thereby do arise, else one of the forms would be eliminated. Probably a dimorphic * species is better protected than one which is non-dimorphic. The larvæ of the former have a wider range of resemblances to the tints and objects of nature, and therefore more chances of concealment and escape from enemies. Dimorphism would also seem to bestow greater adaptability on the part of a species to new scenes. In its wanderings one of its forms may be well protected in the new country; in other countries the other form may be more concealed. The form best in harmony with the new situation would tend to develop, to the subduing and exclusion of the other — a command of resource in which a non-dimorphic species would be far inferior. Natural selection would appear to be the power at work, effecting the disappearance of the less protected variety.

Among perfect insects dimorphism seems to indicate the development of a younger from an older form. One form is usually much rarer than the other, and probably the older of the two. The later development may be ascribed in part to its increased power of protection of the species. Although in

most cases the two or three forms are now distinct, it is probable that they were formerly connected by intermediate gradations. Thus Dr. Wallace describes a butterfly in the Malay Archipelago

FIG. 44.—The pupa of a South African Swallow-tailed Butterfly (*Papilio nireus*) attached to orange tree, and corresponding in colour to its deep green leaves; from Trans. Entom. Soc.

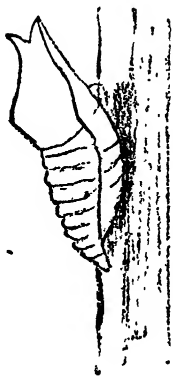

FIG. 45.—The pupa of *Papilio nireus* attached to wood-work, the colour of which it imitates; from Trans. Entom. Soc

which presents a great number of connected varieties, and the extreme links of the chain closely resemble the two forms of an allied dimorphic species inhabiting the same country. Darwin also points out that though with ants the several worker-

castes are generally quite distinct, in some cases the castes are connected together by finely graduated varieties. Probably the variations simply originate in the many slight differences which appear in the offspring from the same parents. No one will suppose that all the individuals of the same species are cast in the same actual mould. These individual differences are often inherited, and thus afford materials for natural selection to act on and accumulate. It doubtless appears a very remarkable fact that a female butterfly (for instance) should be able to produce at the same time three distinct female forms and a male. But these cases "are only exaggerations of the common fact that the female produces offspring of two sexes which sometimes differ from each other in a wonderful manner."[1] I must pass over other phases of di- and trimorphism,* and polymorphism, a mere extension probably of the same principle. Enough has been said to show that this subject is a very wide one, and in many cases extremely perplexing and very obscure.

A series of phenomena remain to be considered which cannot be better described than as by far the highest and most important class of di- or polymorphism. As in dimorphism the species have two or more sets of appearances, but these seem, as it were, under the control of each insect, which is susceptible to the influence of the surroundings, and can at pleasure assume the appropriate form, adjusted

[1] Darwin, *Origin of Species.*

to correspond with its own peculiar environment. In dimorphism proper it is the species that tends to alter its appearance in order to adapt itself to surroundings, due to natural selection, which seizes upon and renders definite variations which are of service to the species. In Variable Protective Resemblance, about to be described, each particular individual is capable of adapting itself, of altering its form, to bring it into consonance, and therefore protection, with the various conditions that it is likely to meet with in Nature. Of the two kinds of dimorphism, clearly that where individual susceptibility is present is of far higher protective value.

It is now a quarter of a century ago since Mr. T. W. Wood, in a paper read before the Entomological Society of London, stated as the result of observations that the pupæ of certain Lepidoptera corresponded in colour to their surroundings. The "Garden Whites" he had found to be dark on tarred fences and in subdued light, while these pupæ were light-coloured when attached to light surfaces. In the same way the chrysalis of the Large Tortoiseshell Butterfly (*Vanessa polychloros*) was coloured like a withered leaf when suspended among foliage. It was then light reddish-brown with metallic silvery spots, while a specimen from a wall was mottled gray and the metallic spots were not produced. Between 1867, the date of these announcements, and the present day, the experi-

ments of various observers have confirmed the truth of the general principle involved in Mr. Wood's researches. By exposure of pupæ of Lepidoptera to different surfaces, it has been proved beyond doubt that many possess the power of adjusting their colours to the normal surfaces to which they are fixed (see Figs. 44 and 45). This extraordinary capability is only present in exposed chrysalides.* Most of the chrysalides of butterflies are freely exposed; the majority of moths pass their pupal period in burrows in the earth, or enveloped in thick cocoons, and among these sensitiveness to surroundings is probably entirely absent.

Up to 1886 the fact of the power of adjustment was really all that was known concerning this strange phenomenon, and the manner in which the colours of these pupæ are determined was a mere matter of speculative theory. In that year Mr. Poulton commenced his elaborate series of investigations, which have thrown a flood of light on this important subject. It was then accepted by Mr. Wood, and by most naturalists interested in the question, that the skin of the pupa was photographically sensitive for a few hours only after the caterpillar's skin had been shed. Comparison was made with the sensitive photographic plate, which darkens under the influence of light. Professor Meldola, however, subsequently showed this photographic sensitiveness of chrysalides to be a mistake, for "the action of light upon the sensitive

skin of a pupa has no analogy with its action on any known photographic chemical. No known substance retains permanently the colour reflected on it by adjacent objects." This groundless, though very plausible, theory was completely overthrown by Mr. Poulton's simple experiment showing the animal's period of susceptibility to surroundings to be in fact previous to the development of the pupal form. From a small number of freshly-found pupæ he removed one, immediately after the larva skin was shed, to a substance of another colour, known to produce an opposite effect upon the pupa, leaving the rest of the company on the accustomed site. The pupa taken, like the pupæ left, resembled the larval surroundings, and not the subsequently chosen surface. Clearly the surroundings had exercised their influence ere the pupa was removed.

So much certain, Mr. Poulton[1] had now to ascertain the exact period of susceptibility to surroundings of these organisms.* He first aimed at making careful note of everything that happens to a caterpillar between the cessation of feeding and the change to pupa, for he felt sure that the time of susceptibility lay somewhere within these limits. When the caterpillars with which the experiments were conducted are full-fed, he tells us, they descend from the food-plant to the ground,

[1] I am indebted to Mr. Poulton's *Colours of Animals* for this account of his researches.

and wander about in search of a surface on which to pass the pupal life. This Mr. Poulton denominates stage I. Having selected the spot the insect rests motionless upon it — stage II. Lastly the larva suspends itself head downwards — stage III. At the end of this time the skin splits, exposing the chrysalis which eventually generally gets rid of the now useless larval skin. Stage I. seemed to Mr. Poulton to be out of count as the period in question, since even if the caterpillars were then susceptible, "no effective results could be obtained; for they are then wandering over surfaces of various colours, of which few can be the same as that which will form the environment of the chrysalis." Mr. Poulton exposed larvæ to one colour during stages I. and II., and transferred them to another colour for stage III.; other larvæ were exposed to each of the colours for all three stages; and the effects were compared. Stages II. and III. both showed themselves sensitive, but stage II. is more sensitive than the other. For the larvæ which Mr. Poulton exposed to gilt surroundings during stage II. and to black afterwards, "were lighter than those which had been exposed to black during stage II. and to gilt afterwards." That both stages are sensitive is proved by the fact that "the black and gilt surroundings produced still greater effects when they operated for the whole period before pupation."

Thus the old theory of photographically sensi-

tive chrysalides falls to the ground. As Mr. Poulton points out, the adjustment of the pupal colours to their surroundings is due to larval susceptibility, and the larva itself has ceased to be highly sensitive many hours before pupation. That stage II. is the great period of susceptibility, probably explains the true meaning of the motionless rest of the larva on the surface upon which it will pupate; while stage III. has other meanings connected with the rapid pupal changes that are taking place.

The next question was to determine the organ or part of the larva which is affected by surrounding colours. Mr. Poulton thought that the eyes (*ocelli* *), or the bristles which cover the caterpillars, might be sensitive. Neither of these proved to have anything to do with the influence. In one set of experiments, out of a number of larvæ placed in the same surroundings, half the company were deprived of their bristles, yet the pupæ from the normal and from the mutilated insects were identical. Many other experiments in which half of the larvæ were precluded from using their eyes, showed conclusively that the sensitive organs had some other position in the animal, for the resulting pupæ from both sets of larvæ were alike. Mr. Poulton was thus driven to believe that the general surface of the skin of the caterpillar is susceptible to colour. To test this conclusion, he subjected the body of the same larva to two conflicting colours, producing the most opposite effects

upon the pupa. A careful comparison of all the pupæ obtained in these experiments, with pupæ obtained from larvæ fixed to one colour only, showed that the resulting colours tended to correspond with the surface to which the larger area of skin had been exposed. This occurred whether the head formed part of that area or not, so that the part of the body containing the head is not more sensitive than the other part, confirming Mr. Poulton's experiments to the effect that the eyes have nothing to do with the influence. The influence of two colours did not produce parti-coloured pupæ, as some observers had suggested might be the case. Had parti-coloured pupæ been obtained, it would seem probable that the light acts directly upon the skin. Since they were not obtained, it would appear that the light affects the termination of nerves in the skin, "and that the pupal colours are produced through the medium of the nervous system."

FIG. 46.—The larva of Peppered Moth (*Amphidasis betularia*) reared amid green twigs and leaves.

It should be especially noted that certain dimorphic pupæ show not the slightest trace of susceptibility to the surroundings. The chrysalis of the Swallow-tailed Butterfly (*Papilio machaon*), for instance, appears in two forms, being sometimes dark

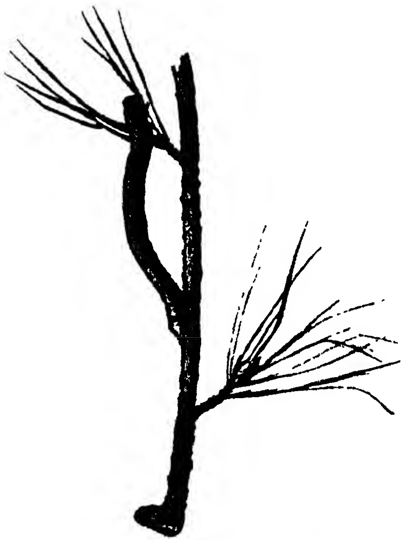

FIG. 47.—The larva of Peppered Moth reared amid dark-brown twigs as well as leaves.

and sometimes green, but these chrysalides have no power of adjustment to dark and green surfaces respectively. Fritz Müller, experimenting upon a South American Swallow-tail (*Papilio polydamus*) which, like our own, has dimorphic pupæ, found that the latter are equally non-sus-

ceptible to the influence of adjacent colours. The caterpillars of some of the Mocha Moths (*Ephyridæ*) are also of two varieties, and the pupæ developing therefrom appear in two colours, answering to those of the larvæ from which they sprang. These pupæ, which differ from the pupæ of many moths in being freely exposed, are likewise insensitive to the tints of their environment.

Proceeding now to Variable Protective Resemblance in larvæ, the larva of *Cucullia tanaceti* is white when it is feeding on the leaves of the mugwort or tansy, but changes to yellow when it is confined to the flowers of the latter. Long ago Fabricius observed that the larva of *Bryophila algæ* varied in colour according to the nature of its food-plant, being yellow when found on *Lichen juniperinus*, and gray when on *Lichen saxatilis*. The larva of *Cleora lichenaria* is wonderfully adapted to the lichen on which it feeds, and differs in shade of colour as it occurs on a light- or dark-coloured plant. Another example of similar variation is afforded by the caterpillar of the Eyed Hawk Moth (*Smerinthus ocellatus*), which is whitish gray when feeding upon certain kinds of willow, and of a bright yellow green when on other species of willow. The fact that the colour of the caterpillars of certain species may differ according to the colour of the plant on which they occur, is especially noticeable in caterpillars living upon the petals of flowers, or other parts of brilliant hue.

This variability has long been known, and it was most natural to suppose it due to the direct action of the chlorophyll or colouring matter of the different kinds of leaves on the tissues of the insects, the more so from the total absence of green among internal feeding larvæ, while the number of arboreal feeders so coloured is legion. This cause of colour certainly suffices in many transparent caterpillars. But in other cases the adjustment arises from something very different, — in fact the larvæ are affected by the colour of the leaves as surroundings, and not by the leaves as food. Having regard to the experiments on pupæ, Mr. Poulton considers it probable that reflected light influences the skin.

The investigations which he undertook in proof of this were laborious, and very numerous. Leaves were sewn together, so that the larvæ were exposed to the upper or the under side alone, although they ate the same leaf in both instances. The "bloom" was removed from the under sides of some leaves, while some were left normal. The results proclaimed the surroundings and not the food to be the influencing agent. Species of Geometræ were the subjects of trial. Larvæ were selected which resemble the twigs or bark of their food-plant. Some were surrounded solely by the leaves upon which they fed, and by white or green surfaces; in other cases numbers of dark twigs were mixed with the leaves of the food-plant. In the former

experiments the majority of the larvæ became very light brown or light gray in colour, and quite different from the darker larvæ of the same kinds which were produced when the latter test was resorted to. Mr. Poulton points out that the change is protective, because the lighter larvæ were far better concealed on the green leaves and stems than the darker ones would have been. There are species in which the larvæ become green when they are reared among green shoots and leaves, so that the concealment is wonderfully perfect (see Figs. 46 and 47).

It is a still more interesting fact that the caterpillars of certain species can adjust the colour of their cocoon to the environment. Of this class of Variable Protective Resemblance little is known. The stimulus of surrounding colour surely makes itself felt on the larva, and probably the effects are produced through the medium of the nervous system. The power of colour variation in perfect insects as the result of a stimulus, in correspondence with the prevailing tint of the district, also awaits investigation.

The cases of ordinary protective resemblance, as we have seen, can be well explained by the operation of natural selection. Given the rudest resemblance to their surroundings in the first place, those insects which best possessed this qualification even in the most minute degree, would tend to escape destruction, and their less fortunate fellows

would fall victims to their foes. Generation after generation this selecting action would continue, until those most wonderful appreciable disguises imitative of a leaf or some such object had been built up and perpetuated. Indefinite variation is controlled by natural selection, and heredity is an important element. It is to be observed that no explanation is given of the *cause* of the original variations in the colour of the insects; in a word, no explanation is offered of the origin of colour. Some authorities have believed that we find in colour a result attributable to the direct influence of surroundings accumulated through heredity. The preceding experiments on Variable Protective Resemblance showed the medium of the nervous system to be indispensable, so that the results are indirect.

It must not be thought, however, that variable protective resemblance is yet in part due "to the accumulation through heredity of the indirect influence of environment working by means of the nervous system."[1] The power of adjustment of colour possessed by each insect is essentially adaptive. Bias to particular colour through the influence of ancestors would at once weaken the efficacy of the property, inasmuch as different individuals are likely to meet with different environments. But here also, as in all other cases, the power is to be explained by the operation of natural selection.

[1] Poulton.

The primary variations are controlled and quickened by it. *Its* function is to take advantage of a faculty, regardless of the manner in which it originates and at what period of the insect's life the change is induced. The power of changing colour is beneficial to the insects that possess it, — this few naturalists will deny. It follows that natural selection will produce and maintain the power, that it will eliminate any variations, or, to express it differently, that it will eliminate individuals which tend to depart from this useful capacity.

CHAPTER VII

DEFENCES OF INSECTS OR PROTECTION AS DERIVED FROM COLOUR (*continued*)

A conspicuously coloured group — Objection to colour — Different modes of insects of maintaining existence ; possession of nauseous properties, irritating hairs and spines, the sting, hardness of substance, wonderful vitality, capacity for increase, attitudes — Association of bright colour with distasteful qualities — Bright colour as a warning ; its value — Various combinations of means of defence — Resemblance between Warning Colours and patterns ; determining causes of the repetition — Distinction between Warning Colours and those produced by courtship — Sexual colouring made use of for warning ; its similarity — Conspicuous and nauseous but non-vital parts — One meaning of broad expanse of wing of showy butterflies — Mimicry — Bates first to explain the facts — Butterflies that are objects of mimicry in tropics — their unpalatability indicated by conspicuousness and abundance — True Mimicry as distinct from all warning appearances — The term mimicry — Mimicry a phase of Protective Resemblance — Mimicry of American butterflies, of the Asiatic, of the African, in British Lepidoptera — Especially prominent in female ; interpretation of phenomenon — Affords confirmation of theory that Mimicry is produced by natural selection — "External conditions," "heredity" — An explanation of sexual difference of form and colour — Mimetic analogies among beetles — Hymenoptera mimicked by Lepidoptera, Diptera, Coleoptera, Orthoptera, Hemiptera — Mimicry of Coleoptera — Of ants by spiders — Of verte-

brates — Predaceous insects that resemble their prey, or a form to which their prey is indifferent — The great frequency of Mimicry in insects.

Apart from the insects considered in the last chapter, in whose lives the principles of disguise and concealment constitute so important a feature, the most casual observer of Nature must be struck by the existence of a group in whom the development of brilliant colour and conspicuousness is as marked as are the suppression and absence of these properties in the previous cases. The latter court observation and proclaim their presence; to elude notice every imaginable contrivance seems as it were to be exerted by the former class. In face of the remarkable utility of the assumption of obscure or imitative tints by all animals, and the readiness of the acquisition of means of concealment through the agency of natural selection, it would appear that there ought to be no conspicuous and brilliantly coloured insects.

Where Protective Resemblance is wanting, the idea instantly suggests itself that protection must be gained in some other way. Observation of the life of insects soon shows that, far from being confined to one mode of maintaining their existence, they are in fact possessed of a variety of means by which to defend themselves from enemies and to obtain their food.

All are not equally palatable to insect-eating animals. Experiment places it beyond doubt that

many possess some unpleasant quality, or qualities, rendering them if caught unfit for food, or even disgusting or dangerous. A widely-extensive group is repugnant, and is constantly refused, owing to their possession of a more or less powerful and revolting taste or smell. Almost every order furnishes instances of defensive scents, but few yield individuals more notoriously bad in this respect than the Coleoptera, Orthoptera, and Hymenoptera. Among Lepidoptera, numbers of the larvæ prove distasteful. The chrysalis of the Magpie Moth (*Abraxas grossulariata*), and many butterflies and moths are similarly defended. In some cases an offensive odour is emitted at pleasure from particular organs. The peculiar faculty of the so-called Bombardier Beetles, consisting in the discharge of a volatile liquid like a puff of smoke, accompanied by a distinct crepitating explosion and attended by a disagreeable scent, is well known. An enemy in pursuit is dismayed, and arrested on its progress, enabling the beetle to gain time, and probably to effect its escape. Emission of strongly smelling fluids on the approach of an enemy is by no means unusual. The larvæ of certain Sawflies (*Hymenoptera*) have a number of odoriferous glands along the middle of the ventral surface, moreover these insects are gregarious, collecting, often a hundred and more, on the branches of trees, which they completely denude. In the event of one of the larvæ being

touched or disturbed, it instantly gives forth a drop of a clear resinous liquid from its glands, and, what is still more remarkable, all its neighbours, as though moved by an impulse in common, do the same, a combination of forces which diffuses an atmosphere around the company probably effective in warding off most enemies. Lady-birds (*Coccinella*) can eject nauseous fluids, as can numerous caterpillars. Offensive watery drops may likewise be caused to issue from the bodies of Lepidoptera in their perfect state.

Caterpillars may be protected by the possession of hairs, which would appear capable of causing extreme discomfort on the delicate skin of the mouth. Many persons know how great can be the annoyance experienced in handling some of these hairy larvæ. The hairs shed will sometimes produce inflammation or a rash on the hands, or on the face or neck, should the operator happen to touch these more sensitive parts when getting rid of the minute hairs with which his hands are covered. There is experimental proof that such larvæ are regarded with aversion. Some animals positively refuse to touch them, others may seize them, and will afterwards relinquish them with every sign of dislike and irritation. If to birds the hairy covering is much less unpleasing, it may still be the means of the escape of the possessor from these enemies. When disturbed the caterpillar of the Great Tiger Moth, which is beset with long dense

hairs, usually rolls itself up into a round ball, and is then taken by a bird with great difficulty, judging by its tiresome liability to glide from between one's fingers. Spines and tubercular prominences are likewise present on many caterpillars, rendering them uncomfortable, and maybe painful morsels to assailants. Hairs or spines, however, defend certain species by contributing towards the production of striking protective resemblance.

The sting possessed by the females of many Hymenoptera is a defensive attribute that keeps man himself at bay. Obviously it must enable these insects to enjoy considerable immunity from attack.

FIG. 48.—The larva of Buff-tipped Moth (*Pygæra bucephala*), a caterpillar with Warning Colours and a nauseous taste; from Curtis

Hardness of substance of external parts is probably also protective. The elytra of beetles are often so impenetrable as to be most difficult to pin, and the golden wasps (*Chrysididæ*) which do not sting, have as a substitute the power of rolling themselves up into a ball, which is almost as firm and polished as though it were made of metal. Insects thus endowed must form exceedingly unpleasant and indigestible fare, and will be disregarded by insect-eating animals unless sore pressed by want of food.

In remarkable vitality insects have another

means of defence. Their capacity for increase in other cases is so great that, notwithstanding the destruction of the adults to any number, ample provision seems always to exist for the continuance of the race. Again, some attitudes are protective, such as the simulation of death, or a terrifying posture may be assumed, so as to inspire alarm and repel the enemy.

Insects defended by some of these kinds of protection in a high degree are free, so to speak, to develop colour, for sexual purposes probably, and for the varied uses to which colour may be put among animals; or it would be more correct to say that, some of these defences being adopted, the causes which lead to the development of colour have been enabled to do their work unchecked. It can easily be understood how such defence may be in a measure so perfect as to be adequate for all the wants of the race, and ensure the maintenance of large numbers, in which case the suppression of colour is no longer necessary, and gorgeousness may be developed without harmful effect. Hence among insects best protected in the ways described is found the greatest amount of colour, or at any rate little or no attempt at protective resemblance. To give only one example, the common wasp, the hornet, and many humble-bees which are armed with a formidable sting, are all conspicuous, and not one of the stinging Hymenoptera is coloured to resemble an inanimate or vegetable object.

Bright colour is not only developed for sexual and like purposes; paradoxical as it seems, it may be of high protective value. It acts as a danger-flag, a warning to enemies that the possessor is inedible. This may at first appear to be an advantage to the enemies rather than to the conspicuous forms, and so militates against accounting for the rise and growth of the character by the action of natural selection, for natural selection cannot possibly produce any modification intended exclusively for the good of another species. But the conspicuous insect is benefited by its gaudy colour. It is at once recognised as distasteful, and is unmolested. Had it resembled its surroundings it would have been liable to be seized and tasted, and though it was afterwards rejected in all probability the wounds would prove ultimately fatal. Thus by natural selection have the bright colouration and the distasteful qualities become associated. The association is one easily learned and remembered by enemies, and saves a continual destruction of individuals. The immensity of the benefit derived by the conspicuous species is realised when it is considered how small is the comparative loss of life involved in the education of the enemy.

Let it not be supposed that these varied means of protection are necessarily attended by Warning Colours. Nature is open to too many influences to be able to develop on any such rigid hard and fast plan. Here we find one set of defences in combina-

tion, there another. The gregarious habit of some inedible dull-coloured caterpillars is of itself a "warning," for their offensive odour gives timely notice to an approaching enemy, so that the acquisition of bright colour can be dispensed with. Again the great family of ground-beetles (Carabidæ) are almost all of disagreeable smell, but they do not present very vivid hues, probably because they are mostly nocturnal and predaceous, and it is important that they should be sufficiently invisible at night to creep unseen upon their prey. By day their odour and taste keep foes at a distance, while the metallic tints adorning them, when they are not wholly black, are fairly conspicuous. It must be remembered that the acquisition of an unpleasant quality must precede the appearance of warning colour. The properties that are most commonly accompanied by warning colours are those of bad taste or smell (see Fig. 48), attributes the possession of which it is a matter of great consequence to the solitary individual to conspicuously advertise. It should perhaps be mentioned that there are many cases where brilliant colour has not been experimentally shown to be associated with some distasteful property.

Where colour serves to proclaim danger or inedibility, it is an interesting fact that the signal is a very constant one. The colours that are chiefly acquired by nauseous insects are those that produce the sharpest contrasts, therefore they are the

most easily perceived, indeed they obtrude themselves upon notice, and their number being small the same combinations are inevitably repeated again and again, and by insects of widely different families. Similarly the patterns that are employed are few and pre-eminently conspicuous and simple. In this manner insect-eating animals are not only

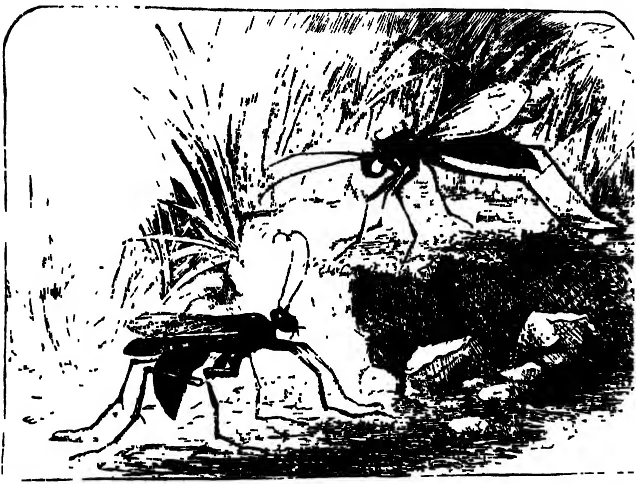

FIG. 49. — Hornet and Mimetic Bug; from Belt.

readily attracted to the signal, they early and quickly recognise unpalatability or danger as a whole, and probably have not to gain experience through trial of every nauseous species in their locality, an education that would be unpleasant and tiresome to the eaters and costly of life to the insects tested. The frequent repetition of the

same colours and patterns in distasteful forms is a necessity, since only a limited number afford the required effect, and the repetition is itself an advantage, and consequently has been encouraged by natural selection.[1]

It would appear to be a difficult matter to distinguish which are Warning Colours. Probably all ornament in mature individuals may be partly attributed to the agency of sexual selection, and has a sexual interpretation. But generally speaking it is easy to distinguish the appearance which has a purely sexual meaning, and that which has been specially modified for other uses as well. The colours produced by courtship are beautiful, more or less blended, the patterns are elegant, whereas, as we have seen, startling and strongly contrasted colours and primitive patterns are evidences of the warning signal; intrinsic beauty gives way before conspicuousness and effect. But besides these differences, the particular value of colour may be judged by the extent of its distribution over the body of the animal. If the colour is widespread, and cannot be veiled during the period of rest, then it proclaims itself to be in most part of warning significance. When it is of importance for warning, no care is taken to hide it, and the flight is slow, so that the adornment is completely displayed. Where the appearance has a sexual value alone the insect mounts zealous

[1] Poulton.

guard over it for the especial purpose of courtship. The flight then is swift and wary, and a characteristic habit is to settle with sudden abruptness.

These two groups nevertheless pass into each other, especially in the Tropics, where colours which strictly are produced by courtship seem to be utilised for warning purposes. In such cases the distribution of colour becomes more general, and the habits indicative of nauseous species are assumed. When warning appearance has been developed by this method, the colours and patterns of the members of each of the groups distinctly resemble each other, with the same good results as when the similarity in the warning colouration has arisen differently.

The resemblance between certain species of unpalatable insects is such that they may be said to mimic each other. This fact was first observed by Bates, and Fritz Müller explains it to be to the advantage of both species, seeing that the destruction of life involved in the education of their enemies is shared, and so falls less seriously on each independently. These remarkable resemblances are comparatively rare, but Professor Meldola applies the same explanation to the general similarity which prevails throughout immense numbers of species in these protected groups. In many cases, the species in each group are closely related, but in some instances the similarity has arisen between species belonging to very different

groups. The resemblance of the Danaids of tropical America to the Heliconias of the same localities probably constitute a most interesting example of similarity of forms which were originally unlike. These Heliconoid Danaids, as they are called, have acquired in a wonderful manner the colours and wing-shape of their models the Heliconias, and are distinct from all the other members of the group. The advantage derived is mutual, for their enemies have to learn only one type of colouring and form and but the same motion in flight.

Obviously the advantage leans greatly to one side where of a group protected by corresponding colours and patterns certain of the number are possessed of comparatively less unpleasant attributes, an imperfection that they effectively hide under the more complete protection of the species resembled. Although these resemblances contain in them an element of true Mimicry, and reap some of its advantages, they must be distinguished from that principle. Those cases where the mimicking and the mimicked species cannot be said to differ as regards their unpleasant qualities approach less near to true Mimicry.

Warning colour and conspicuousness may protect the forms developing them in another fashion. Attention is directed to some unimportant part, which is highly nauseous. If the structure is seized by the enemy, and apparently it is a most convenient point to capture, it breaks off without

harm to the owner, but with such uncomfortable effects on the attacking animal that the former probably escapes unhurt.

In other cases, a non-vital part is particularly attractive but is unattended by unpleasant qualities. The part gives way upon seizure, so that the insect is afforded a chance of escape. This is probably a meaning of the broad expanse of wing of many weak-flying butterflies, and of their bright colouration irrespective of its pronounced sexual utility. Such butterflies are tolerably plentiful, poor as one might deem their opportunities for existence and increase. But specimens are often taken with pierced and broken wings, as though they had been caught and had escaped. Wings that were less showy in flight would not have constituted so good a target, and had they been smaller in proportion to the body the enemy would have been more likely to hit upon a vital spot. Where the butterfly is active, and has well developed protective tints, its brilliant colour — leaving the greater sexual use out of the question — serves as protection in reserve after its other defences have broken through, and attracts enemies to some feature of no importance, when it has failed to elude its pursuer either by its swiftness or by its disguise. This colour differs from Warning Colour proper. It is associated with protective tints, and the enemy, although it makes a mistake, is unaffected by disgust or danger.

We now come to one of the most interesting aspects of our subject, to one the discovery of which admitted of our understanding many of the phenomena that have gone before. Entomologists have been long aware that certain butterflies belonging to widely separated groups possess a strange close superficial resemblance in shape and colour, a resemblance in external parts but not in essential internal structure, a resemblance that deceives, while naturally the mimicking forms are unlike those with which they have any real affinity. The facts were familiar, but no adequate explanation was forthcoming, they were simply regarded as curious and inscrutable until 1862. In that year Mr. Bates' wonderful memoir of the Lepidoptera of the Amazon Valley solved the problem which had been so long a puzzle, and gave impetus to kindred investigation among groups of the Insecta other than the Lepidoptera. Mr. Bates showed the advantage that must be gained by a palatable and non-protected and hunted form if it imitated the conspicuous outward dress and habits of a species, of whose inedibility these habits and conspicuousness were certain tokens, and effectual safe-guards against persecution and diminution of its numbers. The cause of the existence of brilliant colour in butterflies possessed of some attribute unpleasant to

FIG. 50.—An ant-like Spider (*Synageles picata*); from Peckham.

their enemies being thus clearly recognised, it was soon seen that the same explanation applied to many other groups.

The butterflies which are the objects of Mimicry belong chiefly to the two great families Danaidæ and Acræidæ. They comprise many hundreds of species, and inhabit all the warmer parts of the world. The Heliconidæ of tropical America are likewise mimicked. These butterflies are gener-

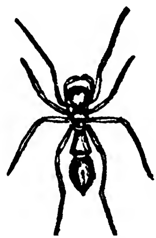

FIG. 51.—An ant-like Spider (*Synemosyna formica*); from Peckham.

ally large, conspicuously and even gorgeously coloured, and their flight is feeble and slow. There is not only disregard of concealment when on the wing, in rest no protective tints are shown, and both surfaces of the wings are equally conspicuous. The abundance of individuals is also striking. These are characteristics indicating unpalatibility, which affords the butterflies immeasurable pre-eminence over their fellows in immunity from attack, depending upon the effectiveness of their colour and habits to give ready warning of

the circumstance. All observers speak of their peculiar and often powerful pungent odour, and it has been noticed that they are constantly neglected and refused by birds of many kinds, and by spiders, dragon-flies, lizards, and monkeys, although all these greedily destroy butterflies which are much less abundant, and which are swifter and less easily captured. The facts point to the possession by these favoured races of a distasteful

FIG. 52.—Adult Caterpillar of the Large Elephant Hawk Moth (*Chœrocampa elpenor*) when undisturbed; from Weismann.

property, which appeals to widely-separated classes of insectivorous animals. In a word the persecution of these butterflies seems to have almost wholly ceased, so that the advantage would be incalculable of being mistaken for them to species less specially protected, and accustomed to be devoured. That the mimickers need to protect themselves is plainly evident, for while the mocked forms abound, almost always in literal swarms, an incontestable proof of their general exemption from destruction, the mockers are often rare insects, and belong to

rare groups, witness equally undeniable of their habitual exposure to danger. The latter appear to be really eatable, and elude their foes solely their counterfeit of the facies* of uneatable well-protected species of the same locality, an imitation such as to deceive the eyes of predaceous birds and insects.

It will be observed that Mimicry aims at the acquisition of Warning Colours. True Mimicry is quite distinct from all warning appearances, although a gradual transition to it from the latter

FIG. 53. — Dorsal view of the Caterpillar of the Small Elephant Hawk Moth (*Chærocampa porcellus*) in its alarming attitude; the posterior "eyes" are inconspicuous in this species; from Weismann.

may be traced. In the close resemblance and imitation between specially protected species, even between most distantly related groups, the similar forms possess nauseous attributes, although they may possess them more or less completely. But in Mimicry the mimicking species are entirely wanting in unpleasant properties, they exist by deceptively assuming the appearance of forms in which such protection is strongly marked. In the former cases the warning colour always acts its own true part. It is an indication, as effectual as possible,

a warning to enemies of real inedibility or danger. As regards true Mimicry, so far as the unprotected mimickers are concerned it is a false signal, a proclamation of a bad quality which has no existence in fact.

Mimicry is an essentially appropriate term for that which it is intended it should designate. It implies deception, mere imitation, a copy, unreality, and this is exactly the character of the resemblances of the unprotected forms in this class of cases. Exception has been taken to the word, because it is ordinarily used in the sense of voluntary imitation, and of course the mimicry here alluded to is not of a conscious nature. Hardly any one will go so far as to believe that the actual volition of the insects has been in any way concerned in the production of these remarkable mimetic analogies. It is true the mimicker often copies the mimicked in flight, and in other habits. But this has probably arisen in precisely the same manner as the imitation of colour and form, by the gradual operation of natural selection, which generation after generation would tend to preserve the individuals whose flight best resembled that of the model, just as it preserved those whose form and colour most closely approached those qualities in the imitated insects. The less perfect degrees of resemblance would be gradually eliminated, and only the others left to propagate their kind. The meaning expressed is

the same in effect as voluntary actions, and in this sense alone the term Mimicry was adopted by Mr. Bates.

Plainly Mimicry is in reality a very important phase of special protective resemblance, it is an adaptation of precisely the same nature. In the one case an insect gains advantage by superficial imitation of a vegetative or some inanimate object, in Mimicry the animal is benefited by superficial resemblance to another living insect. But while in ordinary protective resemblance the simulated appearance is used for concealment, in the case of Mimicry its purpose is to attract attention. The causes involved in the production of the two phenomena are identical. They are the selecting agency of natural selection, the law of the survival of the fittest, or the preservation of favoured races in the struggle for life.

In tropical America, the Heliconidæ and the Danaidæ which resemble them are mimicked chiefly by Pieridæ (*Leptalis*), which are quite distinct from their models in structural characteristics. The Pieridæ is the family to which our common Garden Whites or Cabbage Butterflies belong. Like the specimens at home non-mimetic species of South America .are white, and to these the mimetic * Pieridæ present a striking contrast. Different species imitate those of the Heliconidæ of the same district in the form of the wings, every shade of colour and pattern is copied, the

imitation being carried out to such a wonderful degree as to continually deceive the eyes of the most experienced collectors. The mocking species and the forms mocked usually fly in the same part of the forest, and generally in company, to the evident advantage of the Leptalis. And as if to derive all possible benefit from the association, the mimicking Pieridæ are extremely scarce, while the Heliconidæ are very common, so that it seems hardly possible for an enemy to detect the fraudulent insects, or that it would take the trouble to detect them, even were it aware of their presence. The excessive abundance of the mimicked butterflies wherever they occur, indicates the antiquity and the specially protected nature of the species, and is exactly the characteristic to induce the resemblance.

Besides the Pieridæ, a genus of quite another family of pretty little American butterflies (*Erycinidæ*) mimic the specially protected and dominant forms. The Swallow-tails (*Papilio*), and others, and certain genera of diurnal moths likewise present species which often copy the same favoured creatures. It sometimes occurs in a district, that a species of Leptalis species of two other genera and a moth will all be found mimicking the same Ithomia.

The black and red section of South American Papilios, and a genus of Erycina are themselves in a less degree the objects of imitation.

In the Malayan Isles and in India, the Danaidæ, which are the representatives of the Heliconidæ in the Old World, seem to be the chief models for Mimicry. Papilios in many cases are the mimicking species, taking as their copies different species of Euplœa. On the other hand some Papilios are mimicked.

Parallel series of imitation in the Lepidoptera of Africa have been described by Mr. Roland Trimen. Here again the families Danaidæ and Acræidæ, the last of which have their metropolis in Africa, are attended by their mimics, chiefly Papilios and species of Diadema, a genus allied to our own peacock and tortoiseshell butterflies. Many Acræidæ are models for Nymphalidæ and Papilionidæ. Mr. Trimen gives a list of no fewer than ten species and varieties of Papilio, and sixteen of Diadema, as being perfect mimics of Danais or Acræa prevalent in the same districts. The mimickers constantly accompany the mimicked forms, and sometimes where the sexes of the latter are dissimilar the sexes of the imitators differ accordingly.

Dr. Wallace believes it probable that we find a case of mimicry among British Lepidoptera, in the resemblance of the female of the Muslin Moth (*Diaphora mendica*) to the White Ermine Moth (*Spilosoma menthastri*). The latter has been observed to be constantly refused by young turkeys, and by bullfinches, chaffinches, and other birds of

the kind. It is thus proved to be unpalatable to them, and we may conclude that it is exempt from all attack, which appears very likely because of its great abundance and its conspicuous white colour. The moth Diaphora occurs about the same time of year, and the female alone is white. It is much like Spilosoma, and might easily be mistaken for it in the dusk, while the male is dark, and protectively coloured, so that this species is probably palatable; it is also much less common. All the

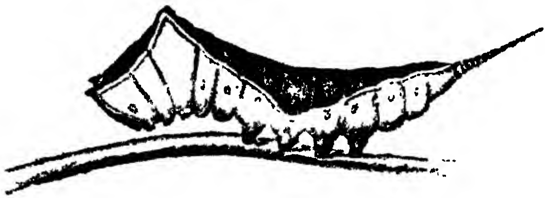

FIG. 54.—The larva of Puss Moth (*Cerura vinula*) resting; full fed; natural size.

facts point to the female Diaphora being a mimic of Spilosoma, standing in the same relation to it as their mimics do to Heliconidæ and Danaidæ. Until the palatability of the supposed mimic is proved, however, this cannot be definitely advanced as an instance of true Mimicry, and must be classed among the close resemblances between unpalatable forms protected by Warning Colours. The affinity between the two species will likewise always exclude it from the best examples of mimicry.

When studying mimetic resemblances among butterflies, the conclusion is forced upon us that the mimickers are very frequently only females, the males retain more or less the appearance of their immediate congeners. In several species of South American mimetic "Whites" (*Pieridæ*), the males are plain white and black, or a portion of the wings is so coloured, it is the females that present rich black and red and yellow hues, barred and spotted to resemble the Heliconidæ. These mimicking females sometimes associate with the abundant Heliconidæ in the shades of the forest, their white males frequent open sunny spots, assembling much with other white and yellow butterflies by the river banks. The superiority of the female in the acquisition of mimetic tints Dr. Wallace ascribes to her greater need for protection than the other sex. Her slower flight, the necessity for her existence until she has sought for a place of safety wherein to lay her eggs, during which time the prolonged life of the male is of no consequence to the continuance of the race — all point to the comparative higher importance of the female insect, and her claim to defence.

Granting this interpretation we obtain strong confirmation of the theory of Mimicry as offered by Mr. Bates, and wonderful support to the argument that the phenomenon is brought about by natural selection. Of the two sexes we have seen that one requires protection most, in many cases

it is that one which mimics the protected forms, while the other whose need is less is frequently non-mimetic. It is therefore clear that Mimicry has arisen through necessity for protection, and this explanation favours the claim that Mimicry is produced by natural selection.

It has been urged that mimetic colouration is due to "external conditions," since female Pieridæ are mimetic of the Heliconidæ with which they associate, while their males whose habits are different are non-mimetic. The fact that the same resemblances occur where the two sexes are alike in habit and fly in the same localities, entirely disproves this theory. Nor is it more feasible to ascribe to "heredity" or reversion to ancestral types a resemblance which exists alone in one of two sexes, which are precisely alike as regards heredity. Mimicry seems to be intimately connected with the well-being of the mimicking species, with its preservation, its direct advantage in the struggle for existence.

Mimicry in the female is of essentially the same nature, and due to the same cause as the fact of the frequently duller tints of female butterflies as compared with the males. The circumstance of the highly specialised forms of protective resemblance to inanimate objects in the females of other orders, whose males show only a very rude approximation, bears the same interpretation. The female is the sex that is disguised. She assumes

the general quiet tints of nature, or she adopts the exact colour and form of a particular vegetative or mineral substance, or as in Mimicry she becomes conspicuous enough, but is in complete superficial resemblance to some other and generally very different creature. The purpose answered is the same in all the cases, viz., protection. In the one case the leaf, or some such inanimate object, is passed over by the enemy, and so the disguise is a safe-guard; in the other the living insect that is resembled is unharmed, and of necessity the resembling insect must share in its immunity.

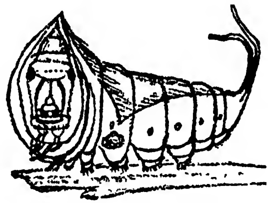

FIG 55 — The larva of Puss Moth in its terrifying attitude; from Trans Entom Soc

That in greater need of protection we find the cause of the difference of colour of the female, whether it consist in decrease or increase of splendour or elaboration as compared with the male, seems corroborated by the fact that where protection of the kind is not required, in other words where protection is procured independently of concealment — for the assumption of mimetic warning colours is in a sense concealment — the colouration of both sexes is nearly or quite the same. In the specially protected and mimicked groups Heliconidæ and Danaidæ, the unpalatability of which seems to be almost universally known among insect eaters, no

sexual difference of colour is exhibited. The same obtains with little variation among other groups of insects possessed of distasteful or dangerous qualities advertised by Warning Colours. For example, in the stinging Hymenoptera, as well as in the Cetoniidæ and Buprestidæ, which are protected by their hardness, the two sexes may be said to be equally well coloured. The probable combined influence of sexual selection in determining the dissimilarity of the sexes is here naturally omitted.

We have found that a Lepidopterous insect mimics another, such only as we have every reason to believe is uneatable, and therefore free from attack, under cover of the appearance of which the weak and decaying mimicking form shelters itself. As might be expected from their usefulness, corresponding imitations exist in other groups of insects. They occur particularly among the Coleoptera, but these are seldom so prominent, so easily recognised, or so interesting, nor have they been subjected to the same full investigation as the beautiful instances in Lepidoptera. We will therefore pass on to consider those cases where the mimicry occurs between species so widely separated from each other as to appertain to distinct orders.

Sometimes the Lepidoptera lose the external appearance of their order.* In two families of British day-flying moths, the Sesiidæ and Ægeriidæ, their wing scales have almost disappeared and the wings have become transparent, while the body is

usually straight and narrow, and the colour has been modified so as to produce a more or less complete resemblance to some stinging Hymenoptera. One of the Bee Hawk moths, *Sesia bombyliformis*, a specific * name recognising the similarity, suggests the appearance of the male of the common Humble Bee, *B. hortorum*. The mimicry of the Hornet Clear-wing, *Sphecia apiformis*, is far more perfect, and better calculated to delude the enemy. This insect is one of the largest of these moths, and is a striking imitation of a hornet or good-sized wasp. The smaller Currant Clear-wing (*Trochilium tipuliforme*), known for the depredations of its caterpillars on the shoots of currant bushes, resembles a small black wasp abundant in gardens at the same season. Little observation has been made on the living appearances of the hundreds of species * of these groups in foreign countries, or how far their habits coincide with those of the Hymenoptera that they specifically resemble. But wherever these analogies occur, their meaning may be inferred to be the same. When we see a moth that has donned the livery of a bee or a wasp, we seem compelled to conclude that the assumption is intended to protect the defenceless form, by deceiving insectivorous animals, even the sharpest, which persecute the moth, but which regard suspiciously, or deal with caution, or at once avoid the Hymenopterous creature whose sting renders it troublesome and dangerous. Certain species of

the clear-wing group have opaque wings, closely resembling those of species of Coleoptera inhabiting the same district. When at rest the wings are closed over the body, like the elytra of beetles.

No order is so frequently mimicked as the Hymenoptera. A number of the Diptera or two-winged flies resemble bees and wasps, and doubtless derive benefit from the freedom of the imitated insects from attack. In the tropics of South America certain large flies mimic stinging Sphegidæ of that country, and a fly of the genus Asilus corresponds in the colour, both of its wings and its abdomen, with the handsome bee *Euglossa dimidiata*, the mocker and the mocked being found in the same localities. A striking resemblance exists between the well-known hornet *Vespa orientalis* and a species of the Dipterous genus Laphria.[1] The mimicked hornet is common round the shores of the Mediterranean, and extends through Upper Egypt, Syria, Arabia, and eastwards into Hindoostan. In colour, size, shape, attitude, and mode of flight, it is accurately copied by its imitator. At home the Drone Fly (*Eristalis*), a very common insect belonging to the Diptera, is marvellously like the male of the ordinary honey-bee as regards form and habits, and is often erroneously called a drone from this circumstance.

Many of the Coleoptera also resemble Hymenoptera. *Charis melipona*, a South American beetle,

[1] *Proc. Camb. Phil. Soc.*, vol iii. Feb. 1877.

is so named from its resemblance to a small Melipona bee. It has acquired a hairy covering on the thorax and body like the bee, and its legs are tufted in a fashion distinctly opposed to that usual on beetles. Another Longicorn Mr. Bates was afraid to touch lest it should sting, it being exactly like a small common wasp of the genus Odynerus. Some Eastern species of the Longicorns adopt the garb of sawflies (*Tenthredinidæ*), and there are many instances of beetles closely imitating the appearance of ants. The latter are excessively abundant in warm climates, and apparently privileged in enjoying general freedom from attack. Turning to England, a common beetle (*Clytus arietis*) resembles a wasp in a striking manner. The waisted body, the characteristic black and yellow bands, and verily the mode of walking of the wasp have been all assumed by its mimic.

Bates mentions several species of crickets (*Orthoptera* *) of South America which resemble different sand-wasps of large size. The wasps are constantly on the out-look for crickets with which to provision their nests, so that it is to the interest of the mimickers to be concealed from the mimicked forms themselves.

Notwithstanding the immense structural difference between the Hemiptera* and Hymenoptera, Mr. Belt describes a Nicaraguan bug which imitates a hornet, and he caught the mimic in his net, fully believing it to be the creature feigned. In respect

of the dissimilarity of appearance of the orders to which the insects respectively belong, this is one of the most extraordinary instances of mimicry on record (see Fig. 49).

The order Coleoptera likewise serves as the pattern for many feeble members of other groups. In the Philippine Isles a pretty cricket (*Condylodera*) is compensated for its real inoffensiveness by the acquisition of the appearance of a dreaded active and predaceous tiger-beetle (*Tricondyla*); even the experienced naturalist Mr. Westwood placed it among the tiger-beetles in his cabinet, and it was long before he discovered his mistake. Both insects occur together on trees, but while the mimicked species is plentiful, the mimicker is rare. The association suggests that the disguise not only shields the cricket from enemies who dislike or fear the mimicked forms, but saves it from the attacks of the beetle itself. In the Amazon valley a locust mimics a tiger-beetle, and is found in the same situation. Another most remarkable instance of these resemblances is that of a grasshopper in the Philippines which resembles a ladybird, whose convex shape is totally unlike its own natural dress. The nauseousness of the little beetle renders it an excellent object for imitation. Frequently the peculiar protection of the mimicked species takes the form of an excessive hardness, such as insectivorous animals fail to crush or to eat. It is easy to understand the benefit that com-

paratively soft-bodied and eatable insects derive from fraudulent reproduction of this indigestible characteristic. This is a defence much mimicked by other, and often distantly related, beetles.

We come now to cases in which the affinity of the resembling forms is more distant still, where the mimicker is distinguished from the species that it mimics by the wide differences that separate two classes of a sub-section of the animal kingdom. Both in the Old and the New World, spiders are known to resemble ants. The deception is often most complete as regards form and colour, and the habits of the imitator carry out the dissimulation. One such mimetic spider caught by Mr. Belt held up its fore-legs to represent antennæ, and they were used in the characteristic manner. In *Synageles picata* and *Synemosyna formica* (see Fig. 51) antennæ are represented by the second pair of legs. The walk and other movements of many of these spiders correspond with those of their models, and differ strangely from the motions of their own allies. Elizabeth Peckham in describing *S. picata* (see Fig. 50), an ant-like spider in North America, states that "by far the most deceptive thing about it is the way in which it moves. It does not jump like the other Attidæ, nor does it walk in a straight line, but zig-zags continually from side to side, exactly like an ant which is out in search of booty. . . . The ant only moves in this way when it is hunting, at other times it goes in a straight line;

but its little imitator zig-zags always." And while it is customary for spiders to remain nearly motionless when they are eating, *picata* "acts like an ant which is engaged in pulling some treasure-trove into pieces convenient for carrying. I have noticed a female *picata* which, after getting possession of a gnat, kept beating it with her front legs as she ate, pulling it about in different directions, and all the time twitching her ant-like abdomen." The ants mimicked are abundant, and as a rule are exempt from persecution. The spiders on the contrary are particularly relished by insectivorous birds, so that there seems good reason for inferring that this mimicry is protective.

Lastly we arrive at the most extraordinary cases of Mimicry, in which the defenceless species assumes the outward dress of a protected form belonging to a different sub-kingdom. Mr. Bates was startled by the strong resemblance of a large South American caterpillar to a small snake. The first three segments behind the head were dilatable at pleasure, and on either side it had a great black pupillated mark, imitating an eye. That a poisonous snake was suggested was evident by the appearance of keeled scales on the crown, produced by the recumbent feet, as the caterpillar raised the anterior end of its body. Among our British caterpillars, that of the Large Elephant Hawk Moth (*Chœrocampa elpenor*) affords a similar example. It occurs in two varieties, a green and a

brown, both being in protective keeping with the colour of their food-plant. On each side of the two first abdominal segments it possesses a large eye-like spot, not in any way specially attractive when the insect is undisturbed, though the marks are somewhat grotesque (see Fig. 52). But upon the approach of an enemy, the caterpillar instantly telescopes its head and thoracic rings into the segments that bear the spots. These segments thus become swollen, and look like the head of the animal, upon which four seeming eyes are very noticeable and terrible of aspect. The inconspicuous insect is at once changed into a serpent-like form, sufficiently surprising to frighten away any would-be assailant (see Fig. 53). Mr. Poulton states that it is the cobra that is simulated in these cases. Like other snakes it has not a large head, and its eyes are small. It inspires fear by its dilated hood with its great eye-like "spectacles," and these features the caterpillar copies in its swollen anterior end and terrifying spots. It is extremely interesting, Mr. Poulton remarks, that the caterpillar should imitate a feature which is merely deceptive in the snake itself.

The assumption at will of a like mimetic resemblance is to be found in the larva of the Puss Moth (*Cerura vinula*, see Fig. 54). When at rest this caterpillar harmonises with the colour of its surroundings, and is well concealed. But as soon as it is disturbed it withdraws its head into the first

body-segment, dilating the margin, which is of a red colour, and on which there are two black spots, like two eyes. An appearance is produced of a huge flat vertebrate face (see Fig. 55). The caterpillar also turns and confronts the enemy. Human beings are alarmed by the attitude, and doubtless it is a protection against the most audacious vertebrate foes of the mimic. This insect is possessed of other means of defence, which may be called into action should the terrifying attitude fail to repel attack. Elaborate and numerous defensive appliances probably indicate a much and long persecuted larva, one that has withstood all the persecution to which it has been liable only by the repeated acquisition of new means of resistance. There is experimental proof that the interpretation of these appearances is correct, and that the assumption of these mimetic resemblances is of real protective value by inspiring insect-eating animals with fear.

In a relatively few cases of Mimicry an insect resembles another so as to be able to injure it. The latter may constitute the prey of the mimic, and by virtue of its deception the predaceous form is enabled to approach its living food without exciting suspicion. Probably the close resemblance of spiders to ants may be explained in this way in a few instances. Bates mentions a Mantis in the Amazons which exactly resembles the white ants on which it feeds.

This Mimicry may allow the aggressive form to lay eggs in the nest of that mimicked, at whose expense the hatched young live, either upon food stored up by their unhappy hosts, or even upon their larvæ. Thus the larvæ of two-winged flies of the British genus Volucella and many tropical Bombylii are parasitic upon the larvæ of particular species of industrious bees. Most of the flies are remarkably like the bees on which they prey, and enter the nests unsuspected to deposit their eggs. *Volucella inanis* resembles the common wasp (*Vespa vulgaris*), but its disguise is less perfect, so that it dares not venture within the portals of its model. It lays its eggs at dusk at the entrance to the abode, giving the larvæ a chance of being accidentally carried in by the wasps, or creeping in of their own accord. As it is, the presumption is said to often cost the mother-fly her life, owing perhaps to the slight failure of the imitative dress, or to the greater intelligence of the wasp as compared with the humble-bee. Hymenoptera also mimic and live upon the labours of home-building species of their own order. Bees of the genus Nomada resemble Andrenidæ, and bees of the genus Psithyrus are almost exactly like the humble-bees (*Bombi*) in whose nests they are reared. On the banks of the Amazon Bates found many of these "cuckoo" bees and flies, which all wore the livery of working-bees peculiar to the country.

There are cases in which the welfare of the

mimetic species is promoted in another way. The insect that resembles another does not injure the latter, but preys upon an animal which accompanies it, or to whom the species mimicked is indifferent. In the opinion of Professor Meldola certain ant-like spiders from Africa, described by Mr. Mansel Weale, are instances of Aggressive Mimicry by spiders for the purpose of preying upon flies, which are often found in company with the ants, and upon which the latter are not predatory. Both the ants and the flies are said to visit the same trees in order to feed upon the sweet secretions, and the former can mingle freely with the flies without causing alarm. The spiders by mimicking the dress of the ants would be enabled to secure an abundant supply of food.[1]

The much greater frequency of Mimicry with insects than with other animals, and the perfection of the phenomenon in them, are probably to be ascribed to their small size and defenceless condition as a whole. These characters, combined with their amazing fertility, the extent to which they are preyed upon by the larger animals, and the quickness of succession of their generations are reasons why the operation of natural selection produces mimetic and other protective resemblances more numerous and more wonderful than in any section of the animal kingdom. Hence the abundance and striking nature of imitation in the

[1] *Proc. Entom. Soc.*, Lond., 1878, p. xiv.

tropics, where insect life is most luxuriant, where the succession of the generations is more rapid, and where the mutual strife between the attacked forms and their attackers is considerably keener than in temperate and cold climates.

GLOSSARY

OF THE PRINCIPAL SCIENTIFIC TERMS USED IN THIS VOLUME.

Abdomen.—The third or tail region of the body. The segments, or rings, of which it is made up, can be more easily distinguished than those of the other regions. In adult insects (with one exception) it is destitute of locomotive organs. Many larvæ, however, have fleshy sucker-feet, or prolegs, attached to their abdomen. These are shed with the skin when the larva changes to pupa.

Abortion.—An organ is said to be aborted when it has been arrested in development at a very early stage.

Alveoli.—Applied to the cells of bees.

Amadou.—A substance prepared from a fungus (*Polyporus fomentarius*), found upon old trees, especially the oak, ash, fir, cherry. Used as a styptic for hæmorrhage. Boiled in a solution of nitre it is employed as tinder.

Amorphous.—Shapeless.

Antennæ.—A pair of jointed appendages, feelers, or horns, placed upon the head of insects, in front of the eyes or between them, and not belonging to the mouth. Of various forms and length.

Anterior.—Placed before, in front.

Apodous.—Footless.

Arachnida.—The Spiders and their allied forms. They constitute a well-defined group within the great division "Articulata" of the animal kingdom. Arachnids are divided into seven orders, of which the Araneidea are the true Spiders.

Articulated.—Jointed. The Articulata is one of the great divisions of the Animal Kingdom characterised generally by the body being divided into a number of rings, or segments,

some of which are possessed of jointed limbs. Insects are included in this division.

Atrophied. — Arrested in development at an early stage.

Aurelia. — (Lat.) Ancient term used for the pupa, or third stage of insect life.

Bi-pinnate. — A pinnate leaf has leaflets on each side of a central stalk or mid-rib. If the division into leaflets is similarly repeated, the leaf is *bi-pinnate.* In this case the leaflets which are attached to the common stalk are termed the pinnæ, and the secondary leaflets the *pinnules.*

Branchiæ. — Gills or organs whereby insects, like fishes, breathe the air that is mechanically mixed with water. They are often plate-like expansions of the body-wall, and are largely supplied with air-tubes, or tracheæ, which are separated from the water only by the thin walls of the organ. Thus the air contained in the tracheæ is readily purified by the air in the water.

Capillary Attraction. — If a capillary tube [that is a tube with a hole so small that it will only admit a hair (capilla)] of glass is placed vertically with its lower end in water, the water rises in the tube to a higher level than the water outside. This has been called Capillary Action, and the term is applied to many other phenomena which depend upon properties of liquids and solids similar to those which cause the action between the capillary tube and the water.

Cecropia. — A genus of trees, order Moraceæ. *C. peltata* is the Trumpet tree of the W. Indies and S. America. Its fibrous bark is used for cordage, and its hollow stem and branches are made into water-pipes and wind instruments. The genus is named from Cecropia, the original name of Athens, in honour of Cecrops its founder, who according to Athenian tradition was first king of Attica. Cecropia was subsequently called Athens by Athena or Minerva, who obtained the right of giving it a name in her quarrel with Neptune.

Cellular. — See Parenchyma.

Chitine. — The peculiar chemical substance which forms most of the hard parts of insects. The chitinous coating, or covering, is formed from underlying skin-cells.

Chrysalis. — A term applied to the third or pupa stage of insects, chiefly that of butterflies and moths. Suggested by the bright metallic spots with which the pupæ of certain butterflies are adorned, from the Greek *chrusos*, gold. Two forms of this word are in use, chrysalis, pl. chrysalides, and chrysalid, pl. chrysalids.

Coarctate. — Straitened, contracted, confined in a narrow compass, inclosed in a case or covering, so as to give no indication of what is within, as the pupa of some flies.

Coccus. — The genus of insects includes the valuable Cochineal. In these the male is a minute active winged insect, while the female does not acquire wings, and in fact is generally a motionless scale-like mass.

Cocoon. — A case, usually of silken material, formed around the body by many larvæ, as those of moths, wherein they change to the resting or pupa stage of existence.

Coleoptera. — Or Beetles, a vast order of insects, characterised, as the name implies, by the structure of the first pair of wings, or elytra as they are called, which are more or less horny, forming sheaths for the protection of the under wings — the true organs of flight in these insects.

Compositæ. — Plants the inflorescence of which consists of very numerous small flowers (florets) arranged upon a common receptacle, and crowded into a dense head (*capitulum*). The Daisy is a common example.

Concentric. — Having one common centre.

Congeries. — A mass of small bodies.

Crop. — A dilation of the œsophagus in insects, serving as a reservoir of food. See *Gullet*.

Dimorphic. — Having two dissimilar forms.

Dimorphism. — The condition of the appearance of the same species under two conspicuously distinct forms.

Diæcious. — The term is applied to species which have the organs of the sexes upon different individuals.

Diptera. — Or Flies — two-winged — comprise insects with only two wings, minute club-shaped organs, called poisers or *haltères*, taking the place of the hinder pair.

Dorsal. — Of or belonging to the back. Relating to the back,

or posterior surface of the body, as opposed to the ventral or anterior surface.

Eccentric. — Removed from the centre or axis.

Elytra. — The forewings of Beetles and Earwigs. They are thick, horny, or leathery, and serve as cases or sheaths for the membranous hind pair of wings, which constitute the true organs of flight.

Embryo. — The young insect in course of development within the egg.

Ephemeræ. — A group of Neuropterous Insects allied to the May Fly.

Epidermis. — The superficial layer of the skin, as opposed to the deep layer — the true skin.

Epiphytal. — Many tropical species of Orchids are called epiphytal — that is, growing in the air, attached to the trunks of trees. Their aerial roots do not reach the soil, they cling to the bark, and are greenish or white. These Orchids derive no nutriment from the tissues of the plant on which they grow, but absorb moisture from the air, and from what trickles down the tree, containing decaying organic and inorganic matter.

Exotic. — Foreign, not native, the opposite to indigenous, meaning native to a country.

Exuvia. — Cast-off skin.

Exuviation. — The process by which animals shed or throw off their old coverings, skins, etc., and assume new ones.

Eyes, compound. — These are situated one on each side of the head, and are of considerable size, and attain a marvellous degree of complexity. Under a microscope they have a honeycomb-like appearance. Each of the little six-sided divisions is in reality a distinct eye, or lens, so that these eyes are compound, or composed of many separate small eyes or ocelli placed side by side; sometimes more than thirty thousand are present. In true larvæ these eyes are wanting.

Eyes, simple. — Usually termed ocelli. Possessed by many adult insects in addition to their compound eyes, between which they are situated, on the crown of the head. Vary in

number, but are usually three. Each resembles a small separate eye of the compound eye. In all insects that undergo a true metamorphosis, ocelli are the only organs of vision in the larval state. In that condition there may be several, and they are fixed on the sides of the head.

Facies. — Appearance, aspect.

Family. — A group of genera having structural features in common, by which they resemble one another, and differ from all other genera. A group of families, similarly associated, constitutes an Order; a group of species, a Genus.

Feelers. — Or palpi, jointed organs, appended to the lesser jaws and inferior lip of the mouth in insects.

Fibro-vascular bundles. — See Parenchyma.

Filament. — A slender thread-like body.

Formicites. — Ants may be divided into three groups, characterised by somewhat important structural differences, viz., Formicites, Ponerites, and Myrmicites.

Fossorial. — Having a power of digging.

Fuliginous. — Of the colour of dark smoke.

Fungus, pl. **fungi.** — A class of cellular plants. Mushrooms and Moulds are common examples.

Fuscous. — Of a dark or blackish brown.

Fusiform. — Shaped like a spindle; gradually tapering at each end.

Gallic. — Denoting the acid obtained from galls.

Galls. — Excrescences, chiefly on the oak, caused principally by the puncture and deposited eggs of the family Cynipidæ.

Ganglion. — A swelling or knot on nerves, a nerve centre containing nerve cells, and receiving and giving out impressions.

Genus. — A group formed by a number of species having characters in common.

Glumes. — The scaly bracts of grasses and sedges.

Gullet, or œsophagus. — Extending into and through the thorax, is the upper or narrowest portion of the alimentary canal, or passage down which food and drink pass from the mouth in animals.

Haltères, balancers or poisers. — Appendages in two-winged flies, believed to represent the absent hinder wings. See

Diptera. In the males of Coccidæ, which also possess only the first pair of wings, the haltères probably aid in flight.

Haustellate. — Furnished with a sucker.

Haustellum. — A sucker. The term is applied to various forms of insect-mouths adapted for suction.

Head. — The first of the three regions into which the body is divided. Like the other regions, it is believed to be formed of several segments, grown or fused together into one mass. The typical body-segment possesses a single pair of legs only. Certain mouth-parts, and other portions of the head, are supposed to be modified legs, and to represent the appendages of several segments, so that it follows that the head is made up of several segments coalesced.

Hemiptera. — An order or sub-order of insects which includes the various species of Bugs. They agree with the succeeding order, or sub-order, Homoptera in the peculiar structure of the mouth, but differ as regards their wings. In Hemiptera the front wings are horny or leathery in the basal portion and membranous at the extremity, where they overlap each other when at rest; in Homoptera they are membranous throughout, and do not overlap. Sometimes wings are wanting in both orders.

Homoptera. — The Cicadæ, Frog-hoppers, and Aphides, or Scale insects are well-known examples. See *Hemiptera.*

Horns. — See Antennæ.

Hymenoptera. — Membrane-winged — an order of insects possessing usually four membranous wings slightly veined. To this group belong some of the most interesting insects — gall-flies, saw-flies, ichneumons, and above all, ants, bees, and wasps.

Ichneumonidæ. — A great family of Hymenopterous insects, the females of which lay their eggs in the bodies or eggs of other insects.

Imago. — The perfectly developed and reproductive state of an insect (usually winged).

Imbricate. — In insects, applied to scales or plates which overlap each other like the tiles of a house.

Insecta. — In its restricted sense this term is applied to those

animals characterised by the possession of only six legs — the Hexapoda or six-footed. They form the largest class of that great division of the Animal Kingdom formerly called Articulata, but for which the term Arthropoda (joint-footed) is now generally adopted Insect comes from two Latin words, *in*, into, and *seco*, to cut, and refers to the fact that the body of the animals thus indicated appears cut or divided transversely into a series of rings or segments.

Insectivorous. — Feeding upon insects.

Jungermannieæ. — A family of the Hepaticæ or Liverworts in which usually a slender stem bears two-rowed minute leaves. Nearly related to the Musci or Mosses.

Labium. — The under lip, the second transverse plate, which bounds the posterior part of the mouth. Its appendages are called labial palpi.

Labrum. — The upper lip, constituting the anterior boundary of the mouth.

Lamina. — A thin plate or sheet-like piece; the flatly expanded blade of a leaf — the most essential part — is so called.

Larva. — The second of the four principal stages of insect-life; the first condition of an insect at its emergence from the egg. During this state the growth of the insect is undergone.

Lateral. — Appertaining to the side of the axis.

Legs. — Insects are hexapodous, or provided with three pairs of legs. In the perfect insect each leg consists of four chief parts, hip, thigh, shank and foot, or scientifically, coxa, femur, tibia and tarsus. Absent in the majority of Hymenopterous and Dipterous larvæ. False legs or sucker-feet are universally present in Lepidopterous larvæ, and others.

Lenticular. — Doubly convex, resembling a lens; bean-shaped.

Lepidoptera. — Scale-winged. An order of insects characterised by the presence, in a greater or less degree, of minute scales on the wings. The mouth consists chiefly of a spiral proboscis. Two groups, Butterflies and Moths, together form this order.

Lethargy. — Morbid drowsiness, unnatural slumber.

Lichens. — The Lichen Family, a distinct class of cellular cryptogamic, or flowerless plants. A lichen usually consists of

a well-developed layer of tissue — the thallus — bearing reproductive bodies. Lichens have a remarkable relation to fungi on the one hand, and to algæ (the sea-weed family) on the other.

Ligneous. — Woody, resembling wood.

Linear. — Like a line. A linear leaf is one that is not only many times longer than it is broad, but is of nearly the same width from the base to near the tip.

Mandibles. — First or upper pair of jaws, opposed horizontally beneath the upper lip; vary much in form; generally strong biting organs.

Mandibulate. — Provided with mandibles, opposed to haustellate.

Maxillæ. — Second or lower pair of jaws in insects, also opposed to each other horizontally and situated below the mandibles, compared with which they are much more complicated. Furnished with jointed appendages called *maxillary palpi* or feelers.

Maxillary Palpi. — See Maxillæ.

Membrane. — A thin layer or skin to cover or wrap up some part of an animal.

Membranous. — Possessing the consistence and structure of a membrane.

Meso-thorax. — The third segment of the body, and second of the thoracic segments. It carries the first pair of wings and second pair of legs.

Metamorphoses. — Or transformations, changes with regard to form.

Meta-thorax. — The fourth segment of the body of an insect, and third or hindermost of the three rings forming the true thorax. It bears the second pair of wings and third pair of legs.

Mimetic. — Applied to animals or organs which resemble each other in appearance, but not in essential structure; appearing like an imitation.

Mishna. — Or text, the codification of the traditionary and unwritten laws of the Jews, believed to have been commenced in the second or third century after Christ. A two-fold com-

mentary by learned Rabbins was subsequently appended to it.

Moulting. — The shedding, or stripping of the skin, or coverings, undergone by insects during their development.

Mouth-parts. — The typical form exists in the biting insects, and consists of six pieces, an upper lip or labrum, an under lip or labium, with two pairs of jaws acting horizontally between them, the mandibles and maxillæ. The maxillæ and labium are each furnished with a pair of feelers, known respectively as the maxillary and labial palpi. No organs in the body vary more than the mouth-parts, but they have been divided into two great groups, the biting and the sucking. Among these many minor differences occur. Thus of the biting insects, some require jaws suited for seizing and tearing prey; others are vegetable feeders, and their jaws are adapted for chewing. Of the sucking insects, some have merely a sucking tube, to sip up the nectar from flowers; others an instrument to pierce the coverings of animals, before they can obtain the living fluid.

Natural Selection, or the Survival of the Fittest. — The natural preservation of such differences and variations as arise, and are beneficial, to the individual, and the destruction of those which are injurious, under its conditions of life. By this principle, the individuals which in any way, even the slightest, have the advantage over others — which are strongest, swiftest, most protected, etc. — have the best chance of surviving, and of propagating their kind.

Neuration. — Or venation, the arrangement of the so-called "veins" or "nerves" in the wings of insects.

Neuters. — See Workers.

Nutrition. — That process, peculiar to living bodies, by which food is finally converted into the substance of tissues and organs, thus repairing waste and admitting of growth.

Nymph. — Old name for pupa. Now generally used to designate the latter portion of the life of an insect with an incomplete metamorphosis, previous to its change to the winged and mature state; an active pupa.

Oblique. — Not perpendicular, not parallel, deviating from the straight line.

Ocelli. — See Eyes.

Œsophagus. — See Gullet.

Order. — An assemblage of families having structural features in common.

Organism. — An organised being, be it plant or animal.

Orthoptera. — Straight-winged. Grasshoppers, locusts, crickets, walking-stick insects, cockroaches, etc. The larvæ when they quit the egg differ principally from the mature insects merely in the absence of wings. They are active throughout life.

Oval. — Egg-shaped, oblong.

Ovipositor. — Generally the most conspicuous appendage of the abdomen is the ovipositor of the female, an instrument whereby she lays her eggs. Its form is various, and sometimes it is of great length. In the Hymenoptera (which see) it is frequently modified into a sting.

Palpi. — Jointed appendages, or feelers, placed on the lower jaws (*maxillæ*) and lower lip (*labium*) of the mouth in insects.

Papilionaceous. — The Papilionaceæ is a sub-order of plants belonging to the large and important natural order Leguminosæ. From a fancied resemblance to a butterfly, the irregular flowers have been called papilionaceous, or butterfly-like. The flower of the garden pea may be taken as the type.

Parasite. — (From a Greek word, meaning one who eats at the expense of another at table.) An animal living in or upon, and at the expense of another. *Parasitic*, growing in or upon, and deriving support from another.

Parenchymatous. — The parenchyma of a leaf is the cellular tissue surrounding the vessels or veins, and inclosed within the covering or epidermis. It contains the green colouring matter. It is a tissue composed of short cells, their diameter being nearly equal in every direction. The *fibro-vascular bundles* constitute the veins.

Pedal. — Appertaining to a foot.

Pedicle. — A small short foot-stalk, a little stem.

Persistent. — Constant, not falling off.

Petiolated. — Stalked, supported on a stem.

Petiole. — Or leaf-stalk, the stalk supporting the blade or lamina of a leaf, and connecting the blade and the stem.

Pigment. — The colouring matter contained in cells produced generally in the superficial parts of animals.

Pinnule. — See Bi-pinnate.

Poisers. — See Haltères.

Pollen. — Usually minute grains or dust produced within the anthers of flowers, and conveyed to the stigma, by means of which the fecundation of the seeds is effected. This fertilisation is brought about by one or more tubes (pollen tubes) which are put forth by the pollen-grains adhering to the stigma, and penetrate through the tissues until they reach the cavity of the ovary. Here they come into contact with the ovules, the bodies that eventually develop into the seeds.

Pollinium, pl. **pollinia.** — In most plants the pollen consists of minute grains, entirely distinct from one another. In some, however, as in the Orchids, the grains are firmly united together by a sticky substance into pollen masses, or pollinia, within the anther lobes.

Posterior. — Placed after, hinder.

Proboscis. — In butterflies and moths, the sucking tube or trunk formed by the modification of the lower jaws or maxillæ.

Process. — A projection, prominence, protuberance.

Prolegs. — Fleshy organs or sucker-feet, enabling caterpillars to grasp firmly stems and other surfaces, and assisting them in their movements. These false or abdominal legs are universally present in Lepidopterous larvæ, in some Hymenoptera, etc. Their structure is often exceedingly curious, as in the caterpillar of the Goat Moth.

Pro-thorax. — The first of the three segments forming the intermediate region of the body known as the thorax. Its appendages are the anterior pair of legs.

Pupa. — The third of the four chief stages in the development of an insect. Often quiescent, but sometimes active. In this state the wings of the adult exist in a rudimentary condition, and from it the insect emerges in the perfect (winged)

reproductive form. The pupa state of butterflies is often called the *chrysalis*, that of insects with an incomplete metamorphosis, as the grasshopper, is frequently designated *nymph*.

Quercus. — A highly important genus of trees, order Cupuliferæ. There are two varieties of British oaks, *Quercus sessiliflora* (*Robur*) and *pedunculata*. *Q. infectoria*, from Asia Minor and Turkey, is valuable for its wood, and especially for its galls, from which tannin and gallic acid are derived, used in ink-making and for photographic purposes. Nearly all the cork of commerce comes from a species of the oak (*Q. suber*) growing in Spain, southern France and Italy, and northern Africa.

Radicle. — The rudiment of the root of an embryo plant.

Ramification. — Division or separation into branches; the issuing or spreading of small vessels from a large one.

Raptorial. — Adapted for seizing prey.

Regurgitation. — The act of pouring or swallowing back by the same orifice or place of entrance.

Respiration. — The act of breathing. The process by which the blood continually absorbs the gas known as oxygen from the air, and gives off in exchange carbonic acid, thus effecting its purification.

Respiratory. — Pertaining to, or serving for respiration.

Reticulated. — Marked like network.

Rudimentary. — In an imperfectly developed condition.

Rufescent. — Somewhat reddish.

Rufous. — Reddish, of a red-brown colour.

Sac. — A bag or pouch.

Saliva. — The fluid or chief secretion of the mouth; derived from various glands.

Salivary. — Secreting or conveying saliva. The *salivary glands of insects* are appendages to the alimentary canal, and open near the mouth. They vary in form and number, and sometimes are not present. In Lepidopterous larvæ they constitute the silk glands, and have a distinct opening through the spinneret (which see).

Segments. — The transverse rings of which the body of an

insect, and of certain other animals, is composed. Their ring-like nature is best seen in larvæ, and in the tail portion of adult insects. In the latter the rings are grouped into three sets or regions, forming the head, the thorax and abdomen. In the larva state this grouping is not distinct.

Skeleton. — The skeleton of an insect is formed of the hardened body-wall or skin, which furnishes support to the softer organs. This hardening is due to the deposition in it of a horny substance termed chitine.

Species. — An assemblage of individuals having structural features in common.

Specific. — That designates the species, or constitutes it.

Spheroidal. — Having the form of a spheroid, *i.e.*, a body approaching to the form of a sphere, or the round.

Spinneret. — A projecting papilla situated within the mouth of many caterpillars, communicating internally with glands which secrete silky material, externally with the outside. Through this organ the material, in the form of a viscous fluid, is forced in two very delicate streams, which unite, and on exposure to the air harden into a single continuous thread of silk.

Spiracles. — The breathing-pores or apertures whereby the internal respiratory system, or breathing tubes (tracheæ) of insects, communicate with the air. Usually situated along the sides of the body, and do not occur on the head. Their number varies, but there is never more than one pair on a single segment of the body. A common form of structure consists of a horny oval ring, within which is a valve, made up of converging fibres, guarding the external entrance. At a short distance within this valve a second may be found, of more complicated form.

Spiral. — Winding like a screw.

Succulent. — Juicy, moist.

Sucker-feet. — See Prolegs.

Suctorial. — Adapted for sucking.

Tarsus, pl. **tarsi.** — The fourth chief division of the leg in insects, that which is popularly called the foot. It is made up of segments, but is liable to numerous modifications. The

distal segment bears one or more claws, which are sometimes strongly toothed, so that there may appear to be four, or even six, claws.

Tawny. — A pale yellow.

Tegument. — Cover, skin.

Thoracic. — Of, or relating to, the thorax.

Thorax. — The second or intermediate region of the body. Formed of three segments, known respectively as the pro-thorax, meso-thorax, and meta-thorax. Readily recognised for its appendages, viz., three pairs of legs, and never more than two pairs of wings. Each segment bears one pair of legs, and in winged insects, the wings are carried by the two hinder segments.

Tibia. — The third chief part or shank of the leg in the perfect insect, coming between the thigh (femur) and the foot (tarsus). In insects that burrow in the ground, this portion is much broadened, and shaped somewhat like a hand.

Tissue. — The elementary or essential structures of which organs are composed.

Tracheæ. — Breathing-tubes of insects communicating with the outside by small mouths, or pores (spiracles). By means of branching, these tubes carry the air through every portion of the insect, so that the various tissues are supplied with oxygen without the intervention of blood, as in the higher animals. The walls of these air-tubes, like the body-wall, are made up of three layers, and the outer layer of the wall of the body corresponds with the inner layer of the wall of the tube. The latter is shed, with the outer skin of the body, when the larva moults. In many adults with powerful flight, the tracheæ are dilated into numbers of minute *sacs*.

Trimorphic. — A species is so designated which presents three distinct forms.

Tubercle. — A small protuberance.

Tuberculated. — Possessed of tubercle-like prominences.

Type. — The perfect representation of anything. *Typical*, applied to an individual which possesses in a marked degree the characteristics of the species, or to a species similarly exhibiting the essential features of the order.

Unctuous. — Fat, clammy.

Valve. — Folds of membrane which guard certain orifices and channels, allowing any fluid to pass in one direction, but offering a barrier to its backward movement.

Venation, or Neuration in Insects. — The arrangement of the so-called "veins" or "nerves" of the wings. A wing is first developed as a tiny sac-like projection from the side of the body. As formation goes on, the two walls of this sac become united throughout their greater part, and various thickened lines are usually apparent, which constitute the framework of the wings, and are termed the veins or nerves. Within the latter a canal or tube often exists for the circulatory fluids, and they are likewise traversed by the air-tubes, or tracheæ. *Venation, in botany*, the arrangement of the ribs and veins, or framework, in the blades of leaves.

Ventral. — Pertaining to the abdomen or anterior surface of the body; the opposite of dorsal.

Vermiform. — Worm-like.

Vertebrate Animals, or Vertebrata. — The highest division of the Animal Kingdom, characterised by the possession in most cases of a backbone or vertebral column composed of numerous joints or *vertebræ*, which constitutes the centre of the hard internal bony framework or skeleton of the body, and protects the central parts of the nervous system.

Viburnum. — (L., the way-faring tree.) A genus of elegant flowering shrubs, belonging to the natural order Caprifoliaceæ — the Honeysuckle family. *V. opulus* is the common Gueldres Rose or Snowball tree, the flowers of which appear in June. So named from a district in the Low Countries, called Gueldres-land, where it is extremely abundant. *V. lantana* is the Mealy Gueldres Rose, sometimes called Cotton Tree from its general mealiness.

Viscous. — Glutinous, sticky, like bird-lime. (L. *viscum*, the mistletoe, a word also applied to bird-lime made from the berries of the mistletoe.)

Weevils. — A family belonging to the great order of beetles (Coleoptera). They may generally be known by a snout or proboscis on the head.

Wings. — Insects have normally two pairs of wings; the Diptera and others, however, have only one pair, while many are entirely destitute of these appendages. When a single pair only is present, it is almost invariably the first pair, and in Diptera, etc., the hinder pair is represented by minute organs, called haltères, balancers, or poisers. Wings vary much in texture, form, nature of surfaces, and venation. As regards the first-mentioned character, the greatest variations are exhibited by the first pair, and special names have been applied to those wings presenting the variations in a marked degree; among these are the *elytra*. Development of wings commences in the early period of larva. After last larval skin is assumed, previous to change to pupa, rudiments of wings begin to form, of the size of pins' heads, beneath external covering of hinder parts of thorax. They continue to grow, and just before this last larval skin is cast, their existence is distinctly indicated by the swollen appearance of the segments. Are much enlarged when insect turns to pupa, and when subsequently pupa skin is burst, the soft thick organs dry, and acquire full expansion. Their gradual formation can be well seen in insects with an incomplete metamorphosis.

Workers. — Females of certain social insects, such as the ant and bee, the sexual organs of which are imperfectly developed. Their function is to perform all the laborious offices for the community. Formerly they were believed to be devoid of sex, and were thus termed *neuters*. Experiments have proved that the cause of this differentiation of sex depends upon the nature of the food with which during the larval state the bee is fed. In all probability, this explanation applies also to ants.

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